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CONTENTS

Petrography, Chemistry, and Possible Correlations of the Camas Land Sill and Teanaway Dike Swarm, Central Washington. *David L. Southwick* 1

Archives Document Preservation. *Rudolf A. V. Raff, Ivan W. Herrick, and Mark F. Adams* 17

Cesium-137 in Litter and Understory Vegetation. *W. H. Rickard* 25

Seed Germination and Flowering in Vallisneria spiralis. *G. N. Choudhuri* 31

Abstracts of Papers To Be Presented at the 1966 Meeting of the Northwest Scientific Association 36

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Petrography, Chemistry, and Possible Correlations of the Camas Land Sill and Teanaway Dike Swarm, Central Washington

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AMONG THE Tertiary rocks in the Wenatchee Mountains of central Washington, four units of basaltic composition were mapped by G. O. Smith in his reconnaissance study of the Mount Stuart quadrangle (1904). The names he used for these units are as follows:

Name	*Age*	*Map Description*
Yakima Basalt	Miocene	Extensive series of lava flows with local tuff beds.
Teanaway Basalt	Eocene	Lava flows with tuff beds.
Basic dikes	Eocene	Diabase, usually quartz-bearing, filling Teanaway Basalt conduits.
Gabbro	Eocene	Intrusive bodies of gabbro, in part olivine-bearing and in part quartz-bearing.

The present study, based on more detailed mapping of an irregular area in the northern part of the Mount Stuart quadrangle and the southern part of the Chiwaukum quadrangle, attempts to clarify the relations among the basaltic rock units tabulated above. The mapped area includes the "Eocene Gabbro" and part of the Teanaway dike swarm. New petrographic and chemical data on these units are presented, and relations of the intrusive rocks to the Teanaway and Yakima lavas are postulated on the basis of petrographic and chemical evidence.

Field Relations and Lithologic Descriptions

"Eocene gabbro" of G. O. Smith (1904)

Under the heading "Gabbro (Eocene)," Smith (1904) grouped a sill of coarse diabase that cuts the sedimentary rocks of the Swauk Formation (Eocene) together with masses of gabbro that are wholly within the "basement complex" of the Mount Stuart block (Figure 1). Several lines of evidence indicate that this grouping is too inclusive.

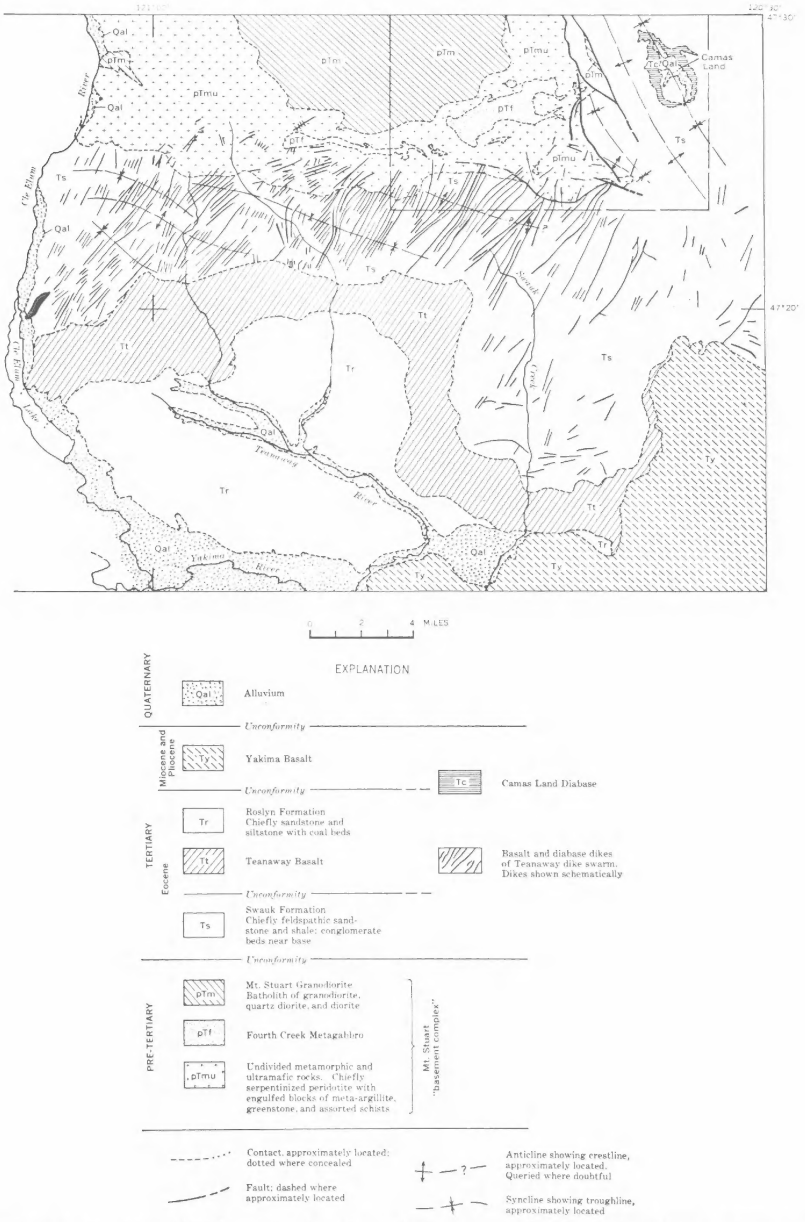

Figure 1. Simplified geologic map of the north half of the Mount Stuart 30′ quadrangle and the part of the Snoqualmie 30′ quadrangle NE of Cle Elum River. The area outlined in the NE corner of the map was studied by the writer. The rest of the map is modified from the Folios of Smith (1904) and Smith and Calkins (1906). Fold axes in The Swauk Formation at the head of Teanaway River are from Foster (1960).

1. The gabbro of the "basement complex" (here named the Fourth Creek Metagabbro for the tributary of Ingalls Creek along which it is well exposed) is moderately to severely uralitized throughout, but the mass cutting the Swauk Formation (here named the Camas Land Diabase for the mountain valley which it underlies) is not uralitized. The Camas Land Diabase contains abundant deuteric zeolites, whereas the Fourth Creek Metagabbro contains none. Many other details of mineralogy and texture also differ (Southwick, 1962).

2. The Fourth Creek Metagabbro is intimately related to a large mass of serpentinite, and together with the serpentinite forms a typical "alpine type" ultramafic complex (Thayer, 1960). This complex is cut by the Mount Stuart batholith and its retinue of porphyry and lamprophyre dikes (Smith, 1904; Southwick, 1962). The Swauk Formation, intruded by the Camas Land Diabase, overlies the ultramafic complex and the Mount Stuart batholith with profound unconformity.

3. Pebbles and cobbles of uralitic gabbro identical to the Fourth Creek Metagabbro occur in basal conglomerate beds of the Swauk Formation, stratigraphically more than 1000 feet below the horizon of the Camas Land Diabase.

It appears, therefore, that the Fourth Creek Metagabbro is Mesozoic or older, whereas the Camas Land Diabase is definitely Tertiary. Because the purpose of this paper is to discuss Tertiary rocks and events, only the Camas Land Diabase is described in detail.

Camas Land Diabase

The Camas Land Diabase forms a sheet that occupies a shallow northwest-trending syncline in massive sandstones of the Swauk Formation. That the sheet is a sill is inferred from regional conformity to the folded sedimentary rocks rather than from contact relations, for the contacts are rarely exposed. Disconformable relations occur on the northeast side of the sheet where a dike-like neck connects the main mass with a smaller tongue emplaced along a lower horizon.

The sill is roughly 3½ miles long, 1¾ miles wide, and ranges in thickness from about 50 feet at the south end to about 500 feet at the northwestern extremity. Its upturned edges underlie steep hills which ring the flat Camas Land valley. Along the north and northwest margins the outer slopes are cliffs from 100 to 400 feet high in which the sill rocks are well exposed. Elsewhere exposures are small and sparse.

Most of the sill is coarse ophitic diabase whose mottled texture is plainly

visible in hand specimen. An unusually light-gray color is imparted to the rock by a high ratio of plagioclase to clinopyroxene. Near the base of the sill the diabase becomes darker and finer grained, and gives way to aphanitic basalt a few feet from the contact. The upper contact zone is not exposed.

A poorly defined layer of equigranular gabbro as much as 30 feet thick occurs about three-fourths of the way to the top of the sill. Besides plagioclase and clinopyroxene the gabbro contains skeletal platelets of magnetite-ilmenite and numerous pockets of stilbite. It grades both upward and downward into ophitic diabase in which magnetite-ilmenite and zeolite are less abundant.

Discontinuous dikelets and schlieren of subpegmatitic gabbro occur in the diabase above the gabbro zone. None was observed wider than 4 inches nor longer than 25 feet. The dikelets pinch and swell abruptly and have highly irregular margins; they branch and fork but bear no discernible relationship to jointing or to the contacts of the sill. Plagioclase and large skeletal plates of magnetite-ilmenite are the dominant megascopic minerals; pyroxene occurs in smaller quantities.

"Basic dikes" (Teanaway Dike Swarm)

The Teanaway dike swarm contains thousands of subparallel basalt and diabase dikes, 5 to 150 feet thick, some of which can be traced for several miles. The dikes occur in an ill-defined east-west belt extending from Wenatchee to the ridges west of Cle Elum River, a distance of more than 45 miles (Smith, 1904). Within this area the greatest concentration of dikes is in an 8-mile stretch due south of the Mount Stuart block. This district is at least 50 per cent dike rock. Most of the dikes are in the Swauk Formation (Eocene), but they also cut all pre-Tertiary units in the "basement complex" (Figure 1).

A striking feature of the swarm is the parallelism of the dikes over most of the swarm area. Individual dikes curve gently and locally are irregular in detail; but nowhere was one dike observed cutting across another. Forking and branching occur but are relatively rare. Only where the dikes cut rocks of the pre-Tertiary complex is this marked regularity disturbed. Apparently the tectonic forces that produce regular *a-c* joints in the folded Swauk strata, up which the dike magma flowed, were deflected and dissipated by the strong but inhomogeneous crystalline rocks of the Mount Stuart block (Southwick, 1962, p. 224 and plate 1).

Many dikes are multiple, and some are composite in that they represent injections of two distinct kinds of basalt. All dikes have sharp contacts, narrow chilled margins, and well-developed columnar cross-joints. One dike

with autobrecciated margins was observed. Contact-metamorphic effects are variable but generally slight.

Two kinds of dike rock can be distinguished in fresh outcrops. One is slightly darker in color and "fresher" in appearance than the other: it has a bright, almost waxy luster whereas the other is paler and dull in appearance. Both kinds are found in dikes of all sizes and degrees of coarseness. The pale, dull dikes seem vastly to outnumber the dark, waxy ones in the area studied. The distinction between them becomes difficult, however, in exposures that are weathered.

Petrography

The Camas Land Diabase

a. Basaltic border phase and peripheral offshoots. The border phase of the Camas Land sill is a porphyritic olivine-bearing basalt with an intergranular to intersertal groundmass. Olivine phenocrysts (Fo_{74-82}) up to 1.5 mm in diameter greatly exceed complexly zoned, inclusion-choked plagioclase phenocrysts in number. The olivine phenocrysts are euhedral and appear to be unzoned, but deep deuteric alteration to montmorillonoids and serpentine prevents 2V determinations near the edges of most grains. Some olivine crystals contain small inclusions of calcic labradorite.

Plagioclase, clinopyroxene, and glass are essential constituents of the groundmass. Plagioclase forms laths from 0.2 to 0.3 mm long that are normally zoned from labradorite cores (An_{52-63}) to andesine rims (An_{40}). Both cores and rims are in the high-temperature (disordered) structural state. Alteration is limited to scattered flecks of kaolinite and sericitic muscovite.

Subcalcic augite ($2V_z = 45°$) is the dominant clinopyroxene, exceeding pigeonite ($2V_z \leqq 10°$) about 10 to 1. Both pyroxenes are pale purplish brown, probably indicating a significant TiO_2 content. In the finest-grained rocks the clinopyroxene is molded between the plagioclase laths. With increasing grain size it gradually coalesces into ophitic plates.

Glass is present in amounts less than 5 per cent and is confined to narrow, wedge-shaped interstices between plagioclase laths. It varies markedly in character from place to place. Fresh, nearly opaque tachylitic glass occurs in a specimen from the floor of the main sill. A pale-brown glass partly devitrified to fibrous silica (?) and zeolites occurs in a small subjacent tongue. In other specimens from the main sill, the glass is completely devitrified to a mass of clay minerals and zeolites.

b. Diabase. About 70 per cent of the Camas Land sill is coarse ophitic diabase. Plagioclase laths from 0.5 to 1.0 mm in average length are set in

clinopyroxene ophites from 1 to 4 mm in average diameter. Thus the rock is on the borderline between diabase and gabbro.

As in the basaltic border phase, calcic plagioclase is the most abundant mineral (Table 1). Laths are normally zoned from labradorite cores (An_{48-59}) to sodic andesine rims (An_{30-36}) and are wholly in the high-temperature (disordered) structural state. The crystals are lightly dusted with kaolinite and, in addition, have been altered to stilbite along cracks and in locally sizable patches. A little quartz, commonly in tiny euhedra, accompanies the stilbite. That the patches and veinlets of stilbite are replacement features rather than simple cavity fillings is indicated by oriented plagioclase remnants and the blebbey, discontinuous nature of the veinlets. Usually the calcic cores of zoned plagioclase crystals are more severely altered than the rims, but exceptions do occur. In places the stilbite appears to have nucleated in the space between several plagioclase grains and to have replaced them radially from the interstitial patch. Optical and X-ray data on the stilbite are given by Chappell (1933, p. 440) and Southwick (1962, pp. 264-266).

Subcalcic augite and pigeonite with the same optical properties as in the border phase also occur in the diabase. Pigeonite occurs most commonly as ragged, embayed cores partly to wholly jacketed by subcalcic augite. A thin rim of greenish montmorillonite may separate the pigeonite from the augite, but more comonly the contact is clean. Grains with augite cores and augite rims also occur. These closely resemble the pigeonite-augite grains; there is no way of telling a pigeonite core from an augite core short of actually measuring the optic angle. Many ophitic plates of clinopyroxene show an increase in birefringence from the center outwards. Careful study of these grains failed to reveal any systematic parallel zoning with respect to 2V. This probably means that the ratio of Ca to (Mg+Fe) remained fairly constant during crystallization, but the ratio of Fe to Mg increased in the later stages. Locally near the base of the diabase the pyroxene crystals display wavy or mosaic extinction. Grains with pronounced wavy extinction usually show strong variations in birefringence as well. Wavy extinction appears to be a crystallographic strain phenomenon connected with some sort of warping during growth. Associated plagioclase shows no evidence of strain, nor is there any indication that the base of the sill has undergone penetrative mechanical deformation.

Olivine is limited to diabase transitional to the basaltic border phase; typical coarse diabase contains none. Accessory minerals are magnetite-ilmenite, hematite, and apatite.

TABLE 1. MODAL ANALYSES OF ROCKS FROM THE CAMAS LAND DIABASE

	Basaltic Margin			*Diabase*						*Gabbroic*	*Horizon*
	C-5	*C-6*	*C-12*	*C8-8*	*C8-6*	*C8-6*	*C8-5*	*C8-4*	*C8-1*	*C8-2*	*C8-3*
Plagioclase	40.3	43.7	39.5	59.9	57.3	53.8	53.0	51.3	53.6	44.8	43.0
Clinopyroxene	34.1	33.5	26.1	25.3	26.5	25.3	22.5	25.4	25.5	26.7	27.0
Olivine and alt. prod.	5.0	5.8	4.6	------	------	------	------	------	------	------	------
Glass and devit. prods.	9.1	4.2	8.8	------	------	------	------	------	------	------	------
Mineraloids[a]	8.3	10.6	15.7	7.6	6.2	10.3	3.7	3.8	4.8	2.9	10.2
Stilbite[b]	------	------	------	3.8	6.9	8.2	17.6	15.4	13.3	21.6	15.5
Opaques	3.2	2.2	5.4	3.2	3.0	2.0	3.2	4.0	2.6	3.7	3.9
Uralite	------	------	------	------	------	------	------	------	------	0.2	0.3
Apatite	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr

[a] Under "mineraloids" are included chlorophaeite and its decomposition products, celadonite, and various montmorillonoids derived from the alteration of ferromagnesian silicates. Montmorillonoids obviously derived from olivine were counted as olivine, and those clearly derived from glass were counted as glass. Those of uncertain genesis were counted as "mineraloid."

[b] Small amounts of quartz intimately intergrown with stilbite were counted as stilbite. No more than 2 per cent of the stilbite entry is quartz. Analyses based on 1250 counted points per standard thin section.

c. Equigranular gabbro layer. Medium hypidomorphic granular texture and an increased content of secondary minerals distinguish the gabbro layer from the enclosing diabase. Plagioclase, the most abundant mineral, is strongly zoned from labradorite cores (An_{58}) to oligoclase-andesine rims ($An_{26\text{-}30}$) and is in the high-temperature (disordered) structural state. Pigeonite and augite form equant grains that commonly show the same zonal relations as in the diabase.

Stilbite is much more abundant in the gabbro than in the diabase, and its replacement relation to plagioclase is very clear (Table 1). Montmorillonoids jacket most pyroxene grains and form independent clumps up to 1 mm across. A few pyroxene crystals have a thin, discontinuous rim of yellowish-green fibrous amphibole. Magnetite-ilmenite forms skeletal plates that are partly altered to hematite. Apatite needles are numerous.

d. Subpegmatitic gabbro. The subpegmatitic gabbro dikelets consist of two distinct parts: a light-colored, zeolite-rich inner zone and a coarser-grained outer zone characterized by large skeletal crystals of magnetite-ilmenite. The inner zone is commonly about one-third the total width of the dikelet and grades into the outer zone over a few millimeters. The contact between the outer zone and enclosing diabase is indistinct over about the same distance. The inner zone is an equigranular rock composed essentially of plagioclase, a little clinopyroxene, and a complex assemblage of stilbite, other zeolites, chlorite, montmorillonoids, and amphibole derived from the deuteric alteration of the plagioclase and pyroxene. The outer zone contains plagioclase and pyroxene crystals up to 8 mm across, and skeletal opaque grains over 1 cm in length. Secondary minerals are much less abundant than in the inner zone. Transition to normal diabase is achieved by increasing the amount of pyroxene and gradually changing the texture to ophitic.

The position of the equigranular gabbro layer in the sill, together with its composition and obvious deuteric alteration, suggests that it crystallized from a late-stage, water-rich residual magma that was slightly enriched in silica. The subpegmatitic dikelets and schlieren in the overlying diabase probably owe their origin to upward streaming of volatiles that had concentrated in the late-crystallizing gabbroic horizon.

The late-crystallizing gabbro layer is the only feature of the sill that suggests any sort of magmatic differentiation. The coarse diabase that forms the bulk of the sill is remarkably uniform throughout, showing no layering on any scale. Cumulate textures are completely lacking.

The "basic dikes" of the Teanaway Dike Swarm

The two megascopically distinct kinds of dike rocks in the Teanaway swarm correspond to the two petrographic types noted by Stout (1961, p. 353). The waxy dikes contain abundant pale-brown glass or its devitrification products and fresh plagioclase whereas the dull dikes have no glass, an interstitial granophyric mesostasis, and altered plagioclase. For simplicity of discussion the two kinds of dikes will be referred to as *glassy* and *holocrystalline* respectively.

a. Holocrystalline dikes. Most of the holocrystalline dike rocks are nonporphyritic and intergranular, consisting mainly of plagioclase laths and clinopyroxene (Table 2). Interstices between the main minerals are filled with a granophyric mesostasis of quartz and albite (?), fibrous zeolite, and an assortment of green montmorillonoids. The coarsest dikes are subophitic.

The plagioclase laths range from 0.2 to 1 mm in length; in general the grain size is proportional to the thickness of the dike, but exceptions to this rule are not rare. The crystals are zoned normally from cores of An_{46} to rims in the range An_{28-35}, and most of them are partly replaced by very fine-grained albite, carbonate, zeolite, and clinozoisite. Commonly the cores of zoned crystals

TABLE 2. Modal Analysis of Teanaway Dike Rocks

	"Holocrystalline"				*"Glassy"*	
	TW-TD1	TW-TD3	P-20	H-12	TW-TD5	M-1
Plagioclase	53.4	51.4	48.7	47.3	34.4	39.1
Clinopyroxene	30.5	30.4	25.6	21.2	13.8	29.2
Olivine and alt. prod.	------	------	------	------	0.4	3.2
Glass and devit. prods.	------	------	------	------	17.8	20.9[a]
Granophyric mesostasis	2.0	3.0	7.5	1.1	------	------
Mineraloids[b]	7.7	8.6	12.7	8.1	28.7	see[a]
Quartz	0.8	1.0	1.2	1.8	0.7	tr.
Zeolites	1.4	1.7	0.2	5.9	------	4.2
Opaques	3.8	3.5	3.8	5.0	3.8	3.4
Leucoxene and sphene	tr.	tr.	tr.	9.0	------	------
Carbonate	tr.	------	tr.	tr.	tr.	tr.
Uralitic amphibole	tr.	tr.	------	tr.	------	------
Apatite	0.2	0.2	0.2	0.4	0.4	tr.

[a] Glass of M-1 is wholly devitrified to an aggregate of tiny plagioclase laths, zeolites, and brownish montmorillonoids. Whatever chlorophaeite was in the rock has altered to similar clay minerals.

[b] Under "mineraloids" are included chlorophaeite and its alteration products and various montmorillonoids derived from the alteration of ferromagnesian silicates. Montmorillonoids obviously derived from olivine were counted as olivine, and those clearly derived from glass were counted as glass. Those of uncertain genesis were counted as "mineraloid." The mineraloid of the holocrystalline dikes is chiefly a deep-green, scaly clay mineral associated with clinopyroxene that has the optical properties and growth habit of saponite. The "mineraloid" of the glassy dikes is chiefly an anomalously deep-green chlorophaeite and its alteration products.

are more severely altered than the rims. Despite the prevalent alteration, the plagioclase is all in the high-temperature (disordered) structural state, suggesting that the alteration was a high-temperature deuteric process rather than a hydrothermal or low-grade metamorphic change. The lack of hydrothermal alteration or metamorphism of the Swauk wall rocks supports this contention.

Colorless to pale-gray clinopyroxene is continuously zoned from pigeonite cores ($2V_z \leqq 10°$) to rims of subcalcic augite ($2V_z = 38\text{-}45°$). Zoning from subcalcic augite cores ($2V_z = 30\text{-}36°$) to augite rims ($2V_z = 50\text{-}54°$) was observed in one specimen. The pyroxene is marginally altered to a deep-green montmorillonoid clay mineral, which has the clumpy, curved growth habit of saponite. Associated with the clay mineral are traces of serpentine, chlorite, and fibrous amphibole. No olivine was found in the holocrystalline dike rocks. In view of the alteration of the other minerals, however, traces of groundmass olivine probably would have altered to montmorillonoids and be difficult to recognize.

Fibrous zeolite occurs in interstitial patches and also appears to be replacing parts of the granophyric mesostasis. Associated with it are sizable patches of quartz.

Accessory minerals are magnetite-ilmenite and acicular apatite.

b. Glassy dikes. The glassy dike rocks are nonporphyritic and intersertal. They consist primarily of plagioclase and clinopyroxene with a small percentage of olivine and abundant glass (Table 2).

The plagioclase laths have core compositions in the range $An_{47\text{-}58}$ and rims in the range $An_{32\text{-}35}$. All crystals are in the high-temperature (disordered) structural state and are absolutely unaltered. Inclusion of magnetite and tiny glass droplets are widespread.

Pale-gray to pale-purple clinopyroxene is zoned from pigeonite cores ($2V_z \leqq 10°$) to rims of subcalcic augite ($2V_z = 40\text{-}42°$) or augite ($2V_z = 50\text{-}52°$). The tendency toward subophitic texture seems stronger than in holocrystalline dikes of comparable grain size.

Olivine occurs in small, anhedral crystals that are partly or wholly altered to clay minerals. The residual grains are too small to allow an accurate determination of composition. Alteration products range from green to orange-brown and are highly birefringent; probably they are montmorillonoids of the nontronite type.

Chlorophaeite and its alteration products (Peacock and Fuller, 1928) are widespread in the glassy dikes. The chlorophaeite is chiefly interstitial but invades adjoining clinopyroxene and glass. When fresh, chlorophaeite is apple green to deep yellowish-green and is isotropic to both light and X-rays.

Alteration produces yellow-green, pinkish-brown, and yellow-brown clay minerals that are weakly to strongly birefringent.

The fresh glass is pale brown and commonly is charged with apatite. Crystallites of plagioclase and pale-brown pigeonite (?) were observed but are rare. Opaque inclusions are surprisingly scanty. The glass devitrifies to an aggregate of yellow-brown clay minerals, feldspar microlites, and zeolites. Spherulitic aggregates of zeolite and clay minerals are developed in some rocks.

Accessory minerals are skeletal magnetite-ilmenite and acicular apatite.

Chemical Composition

New chemical analyses of the basaltic border phase of the Camas Land Diabase and the two varieties of dikes in the Teanaway swarm are given in Table 3. Also included for purposes of comparison are previously published analyses of the Camas Land "gabbro" and Teanaway Basalt, as well as average analyses for various units of Columbia River Group, olivine basalt from the central Cascade Range, and Eocene basalt from the Pacific Northwest.

Regional Geologic Conclusions

From the foregoing petrographic descriptions it is clear that there are significant differences between the Camas Land Diabase (taking the quickly cooled and virtually unaltered border phase as representative of the magma composition) and both kinds of dikes in the Teanaway swarm. The most important differences are summarized in Table 4. The chemical analyses of the three units further emphasize the dissimilarity among them. The Camas Land sill is markedly richer in Al_2O_3, MgO, and CaO than either kind of dike, and is poorer in SiO_2, total iron, and total alkalis. The glassy dikes are far richer in total iron than the holocrystalline dikes; moreover, they are significantly richer in TiO_2 and poorer in MgO and SiO_2.

The petrographic and chemical differences cited above argue strongly against a co-magmatic origin for the sill and dike swarm. Arguments for a co-magmatic origin, as set forth by Smith (1904, p. 6), Chappell (1933, p. 440), and Foster (1958, p. 647), are based almost wholly on the geographic nearness of the sill [actually *all* parts of Smith's Eocene gabbro] to the swarm and do not take into account the compositions of the rocks involved. Foster (1958, p. 647) emphasizes the fact that the densest part of the dike swarm lies close to the supposed Eocene gabbro bodies within the Mount Stuart basement block (Figure 1) and suggests that the gabbro may have been the *source of* the dike magma. He did not realize, however, that the gabbro in

TABLE 3. CHEMICAL ANALYSES OF THE CAMAS LAND DIABASE, TEANAWAY DIKES AND FLOWS, AND OTHER TERTIARY BASALTIC ROCKS OF THE PACIFIC NORTHWEST

	Camas Land Diabase			*Teanaway Dikes and Flows*			*Other Tertiary Basalt Units (Averages)*				
	1.	*1a.*	*2.**	*3.*	*4.**	*5.**	*6.*	*7.*	*8.*	*9.*	*10.*
SiO_2	51.98	53.39	50.43	53.35	55.10	53.54	51.24	49.3	53.9	50.0	49.79
TiO_2	1.71	1.76	1.24	2.44	1.45	1.73	2.01	1.6	2.0	3.2	1.71
Al_2O_3	15.99	16.41	15.14	12.90	12.94	11.70	13.12	15.6	13.8	13.5	16.74
Fe_2O_3	3.10	3.17	2.21	2.21	3.40	6.57	4.33	3.5	2.6	1.9	2.65
FeO	5.88	6.05	7.20	11.28	9.47	9.20	9.15	7.8	9.3	12.5	7.82
MnO	0.10	0.10	0.17	0.25	0.21	0.21	0.21	0.2	0.2	0.25	0.17
MgO	5.09	5.23	8.82	2.68	3.75	1.89	4.26	6.5	4.1	4.4	7.16
CaO	9.68	9.94	10.11	6.96	7.76	7.48	8.61	10.3	7.9	8.3	9.07
Na_2O	2.71	2.77	2.10	2.83	3.23	2.71	2.40	2.7	3.0	2.9	3.32
K_2O	0.81	0.83	0.55	1.40	0.99	1.30	1.01	0.5	1.5	1.4	0.82
P_2O_5	0.31	0.31	0.25	0.45	0.23	0.62	0.61	0.3	0.4	0.7	0.31
H_2O+	2.08	------	1.04	1.76	0.89	1.31	1.46	1.8	1.2	0.9	0.41
H_2O-	0.48	------	0.61	0.91	0.55	1.35	1.20				
CO_2	------	------	------	tr	0.65	------	0.04	------	0.09	0.09	0.32
Misc.	0.04	0.04	------	0.22	------	------	------	------	------	------	------
Total	99.96	100.00	99.97	100.07	99.97	100.16	99.61	100.14	99.9	100.04	99.99
No. of Anal.	1	1	1	1	1	1	4	16	8	4	13

1. Camas Land "gabbro." H. N. Stokes, analyst (Smith, 1904, p. 6).
1a. Analysis 1 calculated on water-free basis.
2.* Fine-grained, olivine-bearing Camas Land Diabase. O. Von Knorring, analyst, 1961.
3. Teanaway basalt flow. H. N. Stokes, analyst (Smith, 1904, p. 6).
4.* Holocrystalline Teanaway diabase dike. O. Von Knorring, analyst, 1962.
5.* Glassy Teanaway diabase dike. O. Von Knorring, analyst, 1962.
6. Eocene basalt, Pacific Northwest (Waters, 1955, p. 705).
7. Picture Gorge Basalt, Columbia River Group (Waters, 1961, p. 592).
8. Yakima Basalt, Columbia River Group (Waters, 1961, p. 593).
9. Upper flows of Yakima Basalt and flows in the lower part of the Ellensburg Formation (Waters, 1961, p. 594).
10. Olivine basalts from central part of Cascade Range (Waters, 1961 p. 595).
* New analysis.

TABLE 4. PETROGRAPHIC COMPARISON OF THE CAMAS LAND DIABASE WITH THE TWO KINDS OF DIKES IN THE TEANAWAY SWARM

Border of Camas Land Diabase	*Holocrystalline dikes*	*Glassy dikes*
1. 5% olivine in large corroded phenocrysts.	1. Olivine absent.	1. Less than 3.5% olivine in tiny, highly altered groundmass granules.
2. Plagioclase fresh; average composition An_{56} (high-temp. str. st.).	2. Plagioclase altered; average composition An_{46} (high-temp. str. st.).	2. Plagioclase fresh; average composition An_{50} (high-temp. str. st.).
3. Glass occurs in amounts less than 5%; tachylite seems to predominate.	3. Glass absent. Interstitial granophyric mesostasis and zeolites total about 4%.	3. Glass comprises 15-20%; pale brown sideromelane appears to predominate.
4. Quartz absent.	4. Quartz common.	4. Quartz rare.
5. Clinopyroxene of border phase is unzoned. Both pigeonite and sub-calcic augite form discrete grains. (Clinopyroxenes of diabase and gabbro are zoned; two generations of pyroxene crystallization discernible.)	5. Clinopyroxene zoned from pigeonite cores to sub-calcic rims.	5. Clinopyroxene zoned from pigeonite cores to sub-calcic augite rims.
6. Fresh chlorophaeite not detected.	6. Fresh chlorophaeite not detected.	6. Fresh chlorophaeite abundant.

question is part of a much older alpine-type ultramafic complex that probably had nothing to do with the dikes.

Both Chappell (1936, p. 384) and Stout (1961, p. 352) have suggested that the altered holocrystalline Teanaway dikes fed the Eocene Teanaway lavas, whereas the fresh, glassy dikes fed the Miocene and Pliocene Yakima flows. I tentatively agree with this conclusion, on the basis of the evidence now at hand. Further study of the area south and east of the present project is needed to clarify the matter completely.

Excellent petrographic descriptions of the Yakima Basalt are available in the writings of G. O. Smith (1904, pp. 7-8), Sheppard (1960, pp. 17-22), and Waters (1961). The Yakima Basalt typically is intersertal with zoned plagioclase laths, subcalcic augite, little or no olivine, varying amounts of chlorophaeite, and abundant brown glass. A late phase contains more olivine, a higher ratio of plagioclase to clinopyroxene, and less glass. This rock has an open, sometimes miarolitic texture tending toward diktytaxitic (Waters, 1961, pp. 600-604). The glassy dikes from the Teanaway swarm are similar to the Yakima Basalt in composition and texture, differing chiefly in the content of mineraloids, especially chlorophaeite, and clinopyroxene (Tables 3 and 5). These differences may stem from differences between the late cooling history of a dike and a flow. Peacock and Fuller (1928, p. 369) and

TABLE 5

	1.	*2.*	*3.*	*4.*	*5.*	*6.*
Plagioclase	41.2	50.2	36.7	32.1	41.0	39.2
Clinopyroxene	31.2	26.9	21.5	33.9	24.5	37.5
Olivine and alt. prods.	5.1	----	1.8	0.7	8.3	4.7
Glass and devit. prods.	7.4	------	19.4	21.9	15.7	6.3
Quartz	------	1.3	0.3	------	------	------
Zeolites	----	2.3	2.1	------	0.5	0.6
Mineraloids	11.5	9.3	14.4	3.1	2.8	5.3
Granophyric mesostasis	------	3.6	------	------	----	----
Opaques	3.6	4.0	3.6	8.3	7.2	6.3
Leucoxene and sphene	------	2.2	------	------	------	------
Carbonate	------	tr	tr	------	------	------
Uralitic amphibole	------	tr	------	------	------	
Apatite	------	0.2	0.2	----	----	----

Average modal analyses of:
1. Camas Land Diabase, border phase.
2. Teanaway *dike rock, holocrystalline* type.
3. Teanaway dike rock, glassy type.
4. Yakima Basalt, Grande Ronde section (Waters, 1961, p. 598).
5. Upper flows of Yakima Basalt and flows in the Ellensburg Formation (Waters, 1961, p. 602).
6. Picture Gorge Basalt, Picture Gorge section (Waters, 1961, p. 597).

Wilshire (1958, p. 138) attribute the production of chlorophaeite to deuteric alteration of primary ferromagnesian minerals. Probably some of the alteration of chlorophaeite to montmorillonoids is also a deuteric process. Presumably the alterations are accomplished by a highly mobile, iron- and silica-rich fluid which streams through the rock after crystallization is nearly completed. Such a fluid might well be channeled in dikes, streaming through them faster and more continuously than through associated flows. As a result, more chlorophaeite and mineraloids might be expected in dikes.

The holocrystalline Teanaway dikes plainly bear no petrographic or chemical resemblance to Yakima Basalt. On the basis of proximity in the field and the available chemical analyses it is reasonable to suppose that they fed flows of Teanaway Basalt, despite the structural arguments of Foster (1958) to the contrary.

If the Camas Land sill is not related to dikes in the Teanaway swarm, what are its affinities? Present evidence permits only speculative answers to this question. There are striking chemical differences between the sill rock and all basalts of the Miocene and Pliocene Columbia River Group (Waters, 1961). It is more impoverished in iron and alkalis and far richer in MgO than any of the Columbia River lavas. Only the Yakima Basalt has as much silica, and only the Picture Gorge Basalt has as much alumina. Perhaps the best chemical correspondence is to the Picture Gorge Basalt. When the chemical analysis of the sill's border phase is plotted in the variation diagrams of Waters (1961, p. 596), the points for each oxide fall closer to the Picture Gorge field than to any other. This correspondence is further brought out by comparing the average modal analyses (Table 5, cols. 1 and 6). This is not meant to imply a direct correlation between the Camas Land sill and the Picture Gorge lavas, for the supporting evidence is suggestive at best. The nearest known approach of Picture Gorge flows to Camas Land is something over 100 miles to the south. The intervening area, however, is covered almost entirely by younger formations beneath which northward extensions of the Picture Gorge Basalt may be concealed.

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Archives Document Preservation

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EMBRITTLEMENT AND discoloration of documents in storage is an aging phenomenon caused primarily by acids present in the paper or formed in the paper during storage. The deterioration is promoted by unfavorable environmental conditions such as humidity, light, and increased temperatures. Consequently, any method designed to preserve documents has to begin with a neutralization treatment without making the paper strongly alkaline at any time. In this respect, Barrow (1964) was successful in checking the high rate of deterioration by soaking modern book papers in solutions containing calcium and magnesium bicarbonates.

The results reported in our study are based on the concept that the incorporation of polymeric buffering agents, such as alkali salts of organic polyacids, will prevent acid degradation of paper by neutralization, and simultaneously reinforce the paper structure by their polymeric film-forming properties. We chose CMC, the sodium salt of carboxymethylcellulose, as the compound most likely to achieve both stabilization and reinforcement in paper. CMC is commercially available in several grades, representing different degrees of polymerization and of carboxyl substitution. It is a water-soluble compound of moderate alkalinity, with proven acid-buffering capacity ("antacid") (Sobue and Tabata, 1956 and 1965; and Hercules Powder Co., 1963), and it is capable of forming films. In molecular structure, the CMC backbone chain is identical to that of cellulose so that compatibility and tight bonding to wood fibers may be expected. In fact, when CMC is applied in aqueous solution to paper by size press, calendar stack, or coating, followed by a drying step, it is known to add to the strength of paper.

We investigated two processes of stabilization: impregnation and lamination. In the impregnation process, CMC was applied to the paper from an aqueous solution. In the lamination process, preformed films of CMC were applied to both sides of the paper sheet. Paper stabilized either way may undergo further protection in the encapsulation process by laminating between sheets of polyethylene-coated mylar.

Test Methods

All testing was carried out after conditioning the samples for at least 24 hours at 22.2°C (72°F) and 50 per cent relative humidity. Evaluation of the various methods of treating paper is based upon the results of tests for fold endurance, tear strength, and pH of the paper, and the effects of accelerated aging upon these properties. TAPPI (Technical Association of the Pulp and Paper Industry) Standard Tests with minor modifications as shown below were applied:

Test	TAPPI Designation	Modifications
Fold Endurance	T423-M-50	Test strip 1.27 cm (½″) wide
Tear Strength	T414-M-49	None
pH	T435-M-52	Cold method used
Heat Stability	T453-M-48	At 100°C

The fold endurance value, determined with a MIT Fold Endurance Tester, is the number of double folds, back and forth through an angle of 270°, which the paper strip can undergo until break occurs. Fold test strips were cut from the paper in such a manner that the crease line was perpendicular to the machine direction of the paper. The tear results, determined with an Elmendorf Tear Tester, are expressed as the average force in grams to tear one strip when 16 notched strips are torn simultaneously. Tear strips were made so that they tore along the machine direction. Accelerated aging was carried out at 100° C to conform to Barrow's report that 72 hours of heating at 100°C produces a degradation in paper equivalent to 25 years of storage at room conditions. For these aging studies, an oven was equipped with a time-temperature recorder.

Impregnation Process

The impregnation of the paper with aqueous solutions of CMC (with or without additives) was carried out by placing the paper strips between blotters saturated with the solutions. The stack was then covered with dry blotters and rolled with a brass roller. The strips were removed, dried on a sheet drier (120°-140°C), and pressed at 100°C and 100 lbs/sq in pressure between teflon sheets.

Treatment of the paper with aqueous solutions of 1 or 2 per cent CMC gave widely varying results, but indications were that high molecular weight CMC imparted better strength than the low molecular weight material. The pH of the treated paper (6.5) was consistently above that of the untreated

sample (5.5). After heating at 100°C for 72 hours, some samples had retained their original strength while others failed immediately in the fold tester. The pH of the heated paper, however, remained consistently around 6.3. Paper stabilized with CMC alone seemed very sensitive to humidity variations, with low humidity favoring embrittlement and high humidity restoring the original strength. We felt that for this reason a plasticizer was needed in the paper.

With solution containing 2 per cent CMC and 20 per cent glycerol as the plasticizer, we noted spectacular increases in fold strength. However, glycerine proved too volatile during the heat-aging procedure, and the resultant samples gave very irregular test results. Therefore we undertook a search for a plasticizer as effective as, but more permanent than, glycerol.

Polyethylene glycols and polypropylene glycols of varying structures and molecular weights did not show the reinforcing effect of glycerol; while di-, tri-, hexa-, and deca-glycerols gave the reinforcing effect but were still too volatile. Encouraging results were obtained when a nonvolatile, water-soluble, film-forming poly(ethylene oxide) resin (Polyox, Union Carbide Corporation (1964)) was added to the solution of CMC. The lowest viscosity grade of Polyox gave the best results, and a small amount (0.25 per cent) added with the CMC was more effective than larger additions. The results of fold endurance tests shown in Table 1 were obtained on fresh newspaper stock when using the indicated treatment.

While the increase in fold endurance with the CMC-Polyox addition is thus not as spectacular as that observed with glycerol, there is still a significant increase in strength before aging, which, most important, is not lost during the heat-aging step. Actually, the impregnated and aged paper became considerably stronger (69 per cent) than the original untreated sample. Further tests showed that impregnation from the wire side only yielded a paper with better fold endurance than when the impregnation was done from the felt side; while impregnation from both sides gave an intermediate value. Table 2

TABLE 1. IMPREGNATION WITH CMC—POLYOX COMBINATIONS

Treatment	*Fold Endurance*	
	Before Aging	*After Aging (72 hours, 100° C)*
Untreated (original paper)	231	173
CMC only (1 per cent solution)	299	298
CMC + glycerol (1 per cent + 20 per cent solution)	1622	10-100
CMC + Polyox (1 per cent + 0.25 per cent solution)	374	392

Results are averages of six tests.

TABLE 2. IMPREGNATION WITH CMC—POLYOX COMBINATION
Summary of Average Test Results

		Untreated		*Wire Side*		*Felt Side*		*Both Sides*	
Paper	*Test*	*U*	*H*	*U*	*H*	*U*	*H*	*U*	*H*
Newsprint	(0.5 kg)								
	Fold	195	168	240	195	212	194	190	186
WSU Letter-	(1 kg)								
head Bond	Fold	103	64	73	68	-----	-----	88	81
	Tear	28.2	24.5	32.2	26.2	-----	-----	28.5	27.4
	pH	7.0	6.6	7.0	6.8	-----	-----	7.0	6.8
"Onionskin"	(1 kg)								
Copy Paper	Fold	153	72	115	107	189	187	159	152
	Tear	7.9	7.0	7.5	7.0	7.5	7.0	7.5	7.0
	pH	6.1	5.2	7.0	6.6	7.0	6.6	7.0	6.8
Old (1916)	(0.7 kg)								
Legal Bond	Fold	164	60	160	78	159	81	146	78
Paper	Tear	10.5	10.2	10.1	9.8	10.6	10.0	9.7	9.8
	pH	4.7	4.7	5.6	5.4	5.5	5.4	6.3	6.2

Results are averages of eight tests.
U = unheated; H = heated for 72 hours at 100° C.

shows, however, that different papers can behave differently in this respect, but the stabilization and reinforcement effects remain.

Although CMC - Polyox combinations satisfy aging and reinforcing requirements, they still have a serious drawback in that CMC as well as Polyox are water-soluble polymers and remain so after heat treatment. Therefore, paper impregnated with either or both tends to become tacky on moistening. We found that this lack of resistance to water can be overcome by replacing the Polyox resin by a very small amount of a wet-strength resin (Kymene, Hercules Powder Company). (Cross-linking reactions occurring in the resin upon curing at moderate temperatures are usually assumed to be the cause of this effect.) Furthermore, the fold endurance of paper treated with this CMC-Kymene mixture is considerably above that obtainable with the CMC-Polyox combination, which remains after aging. This is shown in Table 3, where a CMC-Kymene 557 combination has improved the fold endurance of the heat-aged sample by 154 per cent over that of the untreated paper.

Thus we have demonstrated that the incorporation of CMC and a Kymene resin into paper increases its strength and stabilizes it so that the strength of the paper after heat-aging is frequently still above that of the original sheet. In addition, a paper with increased wet strength is obtained, with further improvement in this property observed after heat-aging.

Lamination Process

Another possibility of stabilizing and reinforcing paper by the use of the CMC-Kymene system consists of applying thin films (10 microns or less) of CMC to both sides of a sheet dampened with an aqueous dilute solution of Kymene resin. The thin films of CMC were prepared by casting solutions of CMC on polished metal plates, followed by lifting the film after evaporation of the solvent. A sheet of newsprint wetted with a 0.1 per cent aqueous solution of Kymene 557 was placed between two films of CMC, and then sandwiched between two sheets of polished metal. Pressure was applied to this sandwich by a heavy brass roller. The paper sheet with the adhering films of CMC was then removed, dried, and pressed. Some of these sheets were tested "as is," while others underwent heat treatment prior to testing. Table 4 shows that the fold endurance of the treated paper is still considerably (33 per cent) above that of the original, untreated samples.

Encapsulation Process

Papers stabilized and reinforced by either the impregnation or the lamination process can be encapsulated between sheets of cellulose acetate or of *polyethylene*-coated mylar by the application of moderate heat and pressure.

TABLE 3. STABILIZATION EXPERIMENTS ON NEWSPAPER STOCK

(Conc. of solutions: CMC—1%; Polyox—0.25%; Kymene resin—0.1%;
Approximate conc. in paper: CMC—2.5%; Polyox—0.6%; Kymene resin—0.3%)

	Untreated		*Polyox*		*Kymene 557*		*Kymene 754*		*Kymene 917*	
	U	*H*	*U*	*H*	*U*	*H*	*U*	*H*	*U*	*H*
Fold	170	140	190	186	812	432	572	395	375	374
Tear	22	19	29	27	25	N.D.	27	N.D.	28	N.D.
pH	5.5	5.3	6.6	6.5	6.8	6.7	6.6	6.7	6.8	6.7

Kymene 557 is a cationic water-soluble polymer with a nitrogen content of 12.8%; Kymene 754 and 917 are cationic, urea-formaldehyde wet-strength resins.
Results are averages of eight tests.
U = unheated; H = heated for 72 hours at 100° C; N. D. = not determined.

Polyethylene-coated mylar appears to be a particularly good combination for this purpose, in that permeabilities to water vapor and air (oxygen) supplement each other (as shown in Table 5) so that a combination film has both extremely low water vapor and oxygen permeability (Stannett and Yasuda, 1964).

TABLE 4. LAMINATION STABILIZATION EXPERIMENTS

	Untreated		*Treated*	
	U	*H*	*U*	*H*
Fold Endurance	245	199	527	326
pH	5.6	5.4	6.7	6.7

Results are averages of eight tests.
U = unheated; H = heated for 72 hours at 100°C.

Paper stabilized and reinforced with CMC-Kymene resin and encapsulated in polyethylene-coated mylar film withstands extended heating and can be expected to be resistant to prolonged periods of aging even under adverse environmental conditions. Documents, stabilized by our methods and encapsulated, were kept at 100°C for periods up to three months without showing signs of embrittlement.

TABLE 5. PERMEABILITIES OF LAMINATION FILMS (30°C)

	Permeability	
	Water Vapor	*Oxygen*
Polyethylene, high density	180	11.0
Mylar	1300	0.46
Cellulose acetate	75000	7.8

Units: cc. STP/cm/cm^2/sec/cm Hg x 10^{11}.

Summary

We have shown in this study that CMC, the sodium salt of carboxymethylcellulose, a water-soluble, high-capacity buffering agent with moderate alkalinity, effectively increases the pH of paper by a neutralizing action, and that this effect remains throughout heat-aging. We have further shown that CMC, in itself a polymeric cellulose derivative, requires the presence of a nonvolatile plasticizer to maintain flexibility in the treated paper. We found that certain wet-strength resins, used in very small amounts, were effective plasticizers. Paper treated with these CMC-resin combinations increased in fold endurance to such an extent that the fold endurance after heat-aging was in most cases still superior to that of the original untreated and unaged paper. Furthermore, the presence of the resin gave wet-strength to the paper, which

increased on heat-aging. These improvements were shown to apply to the four types of paper tested in the program, namely, newsprint, letterhead bond, onionskin copy paper, and old (1916) legal bond paper. No serious alteration of the appearance of the treated sheets was noticed. We have further demonstrated that this stabilization of paper against deterioration upon aging can be achieved by (1) a solution impregnation process with water as the only volatile solvent; and (2) a lamination process based on the use of very thin films of CMC. Paper stabilized by either process can be further protected by encapsulation between sheets of polyethylene-coated mylar. With air and moisture being excluded by the plastic film, and free or generated acid being neutralized by the CMC, paper treated in this manner will be resistant to prolonged periods of aging.

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*Cesium-137 in Litter and Understory Vegetation**

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ESTIMATES OF the amounts of radioactive airborne debris (fallout) deposited over broad climatic regions can be measured by sampling air, precipitation, or surface soil. Although these measurements serve useful purposes, they provide little information on the amount of fallout deposited directly upon plants and therefore available for transfer to litter-dwelling microorganisms or to herbivorous animals.

This paper reports the radiocesium concentrations in understory plants and leaf litter from three forest stands in 1964.

Stand Location, Sampling, and Analytical Methods

The understory plants and litter of three forest stands, each representative of a widespread plant association in the Cascade Mountains of Washington and each growing under a closed tree canopy, were collected on September 15 just before major leaf fall. The sampling sites were located along State Highway 14, which traverses the Cascade Mountains through White Pass. One stand was located near the pass summit, another 12 miles west of the summit, and one 12 miles east of the summit. Elevations at these sites were approximately 4000, 1500, and 2500 feet respectively. The understory vegetation was comprised of herbs and shrubs reduced in size, vigor, and density as compared with more open stands. Community structure and species composition has probably changed very little since man-made radioactive debris was first introduced into the atmosphere 20 years ago. Differences among levels of radiocesium in vegetation and litter measured in these stands therefore are not attributable to pronounced vegetation changes during this time, i.e., fire or logging.

The conifer stand east of the Cascade Mountains is representative of the *Pinus/Symphoricarpos* association as described by Daubenmire (1952). The only tree species is *Pinus ponderosa,* and the understory is comprised mostly of dwarfed shrubs of Snowberry, *Symphoricarpos albus,* with smaller amounts of *Spiraea lucida, Amelanchier alnifolia,* and *Rosa* sp. The sampling site west

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of the mountain summit consisted of a pure stand of Western Hemlock, *Tsuga heterophylla,* with an understory mostly of salal, *Gaultheria shallon* and *Mahonia nervosa.* The forest stand near the summit is comprised of pacific silver fir, *Abies amabalis,* with an understory dominated by blueberry, *Vaccinium membranaceum,* and lesser amounts of *Ribes* sp. and *Rosa* sp. Some of the more common herbs are *Linnaea borealis, Trillium ovatum,* and *Pyrola* sp.

A 4-by-5-m plot was established in the fir and hemlock stands, and all standing understory plants in the plot were clipped near the litter surface. The loose litter was removed from two 1-by-1-m plots located at opposite corners of the larger plot. The same procedure was followed in the pine stand except the large plot was only 2.5 by 5 m in size. The collected litter consisted almost entirely of the leaves of conifers except in the hemlock stand where mosses, growing intermingled with the fallen leaves, were included in the sample.

The vegetation and litter were placed in separate plastic bags and brought to the laboratory and dried, then milled to pass a 1-mm mesh screen. A 500-ml plastic bottle was filled with milled vegetation and analyzed radiochemically for ^{137}Cs using a 9-by-11-inch sodium iodide (Tl) crystal connected to a multichannel analyzer. Moisture content of the counted sample was determined by drying aliquots at 95 C, and radiochemical results are expressed as picocuries ^{137}Cs per gram dry weight.

Results and Discussion

The amount of fallout intercepted by plants is determined in part by their surface areas, the length of time that above-ground organs are exposed to the atmosphere, the amount of fallout in the atmosphere, and the precipitational regime. The retention of fallout once intercepted by plants depends upon the nature of the surface, whether smooth or pubescent, and the size of the fallout particles (Romney et al., 1963). Only long-lived radionuclides like ^{137}Cs (half-life 27 yrs) persist long enough to become a part of mineral nutrition in plants and animals.

Emergence and abscission of leaves is determined in part by environmental factors. Blueberry leaves at high elevations emerge late in the spring while snowberry leaves at lower elevations emerge early in the spring. The leaves of salal, in contrast to those of blueberry and snowberry, are evergreen and remain attached to stems for a year or more. The leaves of salal are relatively large, thick, and heavily cutinized as compared with those of blueberry. The leaves of snowberry and its associated shrubs are intermediate in size and thickness to those of blueberry and salal.

The relationships between ^{137}Cs concentration to leaf age and surface area per gram dry weight of the dominant understory shrubs are shown below:

Age of leaves: salal > snowberry > blueberry

Surface area/gram: blueberry or snowberry > salal

^{137}Cs/gram: blueberry > snowberry or salal (Table 1).

The ^{137}Cs concentrations of understory shrubs growing in the three different stands were more or less similar (Table 1). The fallout accumulated by snowberry and blueberry is largely a result of spring and summer deposition. Although the leaves of blueberry and snowberry were aerially exposed for only a relatively short time, these plants had accumulated as much ^{137}Cs as did the persistent leaved salal (Table 1). Salal did not accumulate radiocesium in proportion to the age of its leaves. Davis, Watson, and Hanson (1963) suggested that frequent rains in a high-precipitation area might wash fallout from leaves, especially from leaves with broad, smooth surfaces like salal.

The leaves of conifers remain attached to tree branches for several years and then persist as litter for several more years after dropping to the ground. In the coniferous forests of the Pacific Northwest, leaf litter may accumulate for 50 years (Spurr, 1964). Conifer litter therefore contains more than one

TABLE 1. Cesium-137 Concentrations in Litter and Understory Vegetation of Three Forest Habitats in the Cascade Mountains, Washington, 1964

	Picocuries per gram	*Picocuries per square meter*
Pinus/Symphoricarpos h.t.		
Symphoricarpos	6.1	150
Total understory	—	150
Litter (a)	17	20,000
Litter (b)	15	12,000
Tsuga/Gaultheria h.t.		
Gaultheria	6.1	580
Berberis	6.0	86
Total understory	—	670
Litter (a)	37	40,000
Litter (b)	45	31,000
Abies/Vaccinium h.t.		
Vaccinium	9.7	120
All other species	17	170
Total understory	—	290
Litter (a)	73	54,000
Litter (b)	65	54,000

h.t. = habitat type
(*a and b are duplicate samples*)

year's accumulation of radionuclides. Gorham (1963) reported that pine-leaf litter accumulated fallout, although he did not identify the individual fallout radionuclides.

The relationship of ^{137}Cs concentrations in conifer litter from the three stands in relation to inferred precipitational regimes of the three regions is shown below:

Precipitation: Fir or Hemlock > Pine

^{137}Cs/gram: Fir > Hemlock > Pine (Table 1).

The annual precipitation in the pine stands averaged much less than that of the hemlock stands (Figure 1). Summer precipitation was more similar than was winter precipitation. Apparently increased annual precipitation also can contribute to the fallout concentration in conifer litter in the same way that the strontium-90 content of soil was increased (Hardy and Alexander, 1962). Whether the annual precipitation of the high-altitude fir stand

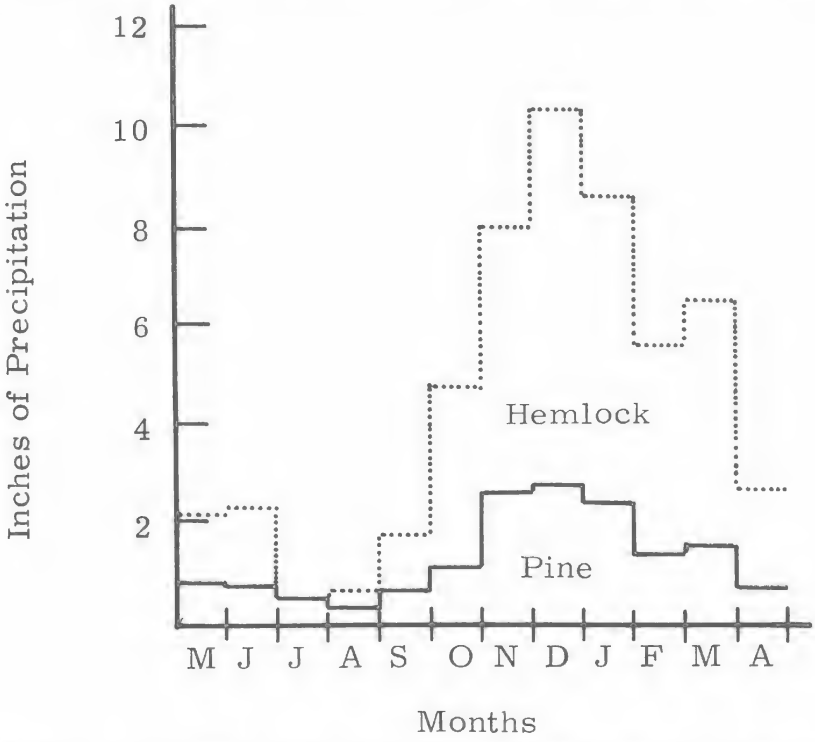

Figure 1. Long-term precipitation averages from Packwood, Washington (Hemlock), and Tieton Range Station (Pine). Data obtained from Yearbook of Agriculture 1941. Climate and Man. U.S. Govt. Printing Office, Washington, D.C. 1248 pp.

greatly exceeds that of the low-altitude hemlock site was not determined, but the cooler climate of higher altitudes permits the accumulation of a deep, long-lasting snow pack. The role of snow melt in increasing the fallout accumulation of vegetation at high elevations has been described by Osburn (1963), and similar processes may be operational here.

The understory plants of the hemlock stand were more luxuriant than those of the other sites; and contained more ^{137}Cs per m^2 of ground than other stands (Table 1). This kind of sampling is especially useful for comparing the amount of organic material available for animal food and microbial decomposition among different habitats.

By sampling leaf litter from many stands representative of widespread forest associations in Washington, it may be possible to use these stands as biologic indicators of the amounts of ^{137}Cs accumulated by forested landscapes during the past 20 years. By using climax stands as base lines for ^{137}Cs values, it seems appropriate that evaluations of the effect of fire and logging on ^{137}Cs accumulations in litter and understory could also be made.

Summary

Cesium-137 derived from worldwide fallout was measured in the understory vegetation and leaf litter of three different mature conifer stands in the Cascade Mountains of Washington in September, 1964. The ^{137}Cs concentration of understory shrubs was more or less similar among the three stands. However, more ^{137}Cs was present in the understory in the hemlock (*Tsuga heterophylla*) stand when expressed as ^{137}Cs per square meter of ground because of the more luxuriant understory growth in this habitat. Cesium-137 in leaf litter was most abundant in a fir (*Abies amabilis*) stand near the mountain summit. The leaf litter of a hemlock stand in a high-precipitation region west of the mountains had higher ^{137}Cs concentrations than did the litter from a ponderosa pine (*Pinus ponderosa*) stand from a lower-precipitation region east of the mountains.

Acknowledgements

The permission of the United States Forest Service to collect plant samples is gratefully acknowledged.

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ASSOCIATION NEWS

Preparations are continuing for the 39th annual meeting in Missoula, Montana, on the 15th and 16th of April, 1966. Programs will be sent to all members in March. In addition, a registration card and return envelope will be included. You are urged to preregister and thus decrease the jam that has plagued us for many years at the registration table. Nonmembers may request a program from the secretary-treasurer (B. V. Ettling, College of Engineering, Washington State University, Pullman, Washington 99163).

E. E. Tylutki, Associate Editor

Seed Germination and Flowering in Vallisneria spiralis

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Vallisneria spiralis is a widespread species occurring from tropical (Bengal, India) to cool temperate climate (Canada) and inhabiting temporary as well as permanent bodies of water. Over such a great range of environments the various phases of life cycle must be regulated by very different conditions. This paper presents the results of studies aimed at discovering what ecologic responses permit this submerged aquatic plant to grow successfully in the region of Varanasi, India, near the southern edge of its latitudinal distribution.

Germination Studies

The usual unresponsiveness of seeds of aquatic plants to normal germinative conditions has led some to believe that normal propagation by seeds might not be as effective as vegetative means, or even in certain cases entirely ineffective as a means of perpetuation of the species. Seeds of *Vallisneria spiralis* are quite unresponsive to external conditions that would seem to favor germination. In nature the seeds mature during the late winter (cool and dry in Varanasi), and the seedlings appear in the early autumn (the end of the hot rainy season).

Crocker (1907) has shown that a number of aquatic plants produce viable seeds, but that seeds of most of these plants fail to respond to normal germinative conditions because their embryos remain covered by impermeable seed coats. If the seed coats are removed, the seeds germinate promptly.

In order to determine whether or not Crocker's findings are applicable to the seeds of *Vallisneria spiralis,* the following steps were taken. Ripe seeds were collected when mature in January from the ponds in Varanasi. They were immediately freed from the pulpy fruits by removing the pericarp in a slow-motion homogenizer, washed well, spread out over cheese cloth for drying, and subsequently stored in paper envelopes under normal laboratory conditions. The dried seeds were treated for lengths of time ranging from 1 to 10 minutes in a volume of concentrated sulfuric acid equal to about five times the volume of the seeds, and were stirred continuously with a glass rod. They were then washed thoroughly in running tap water for about 10 minutes, and placed in petri dishes containing water; temperature was held at 30° C until germination. The seeds were considered germinated

when the coleorhiza protruded through the seed coat to an extent of 2 mm. The percentage germination and the time required for the initiation of germination are shown in Table 1. The germination percentages in the tables represent averages of five replicates of 100 seeds. A treatment time of three minutes seems to be sufficient to render the seed coat water-permeable. These findings are similar to those reported by Crocker (1907).

TABLE 1. Percentage germination and the time required for initiation of germination of seeds of *V. spiralis* after treatment with concentrated sulfuric acid, for varying periods of time. Test was made at temperatures around 30° C.

	Time of Treatment in Minutes			
	1	3	5	10
Days to begin germination	8	3	4	—
Maximum per cent germination in 10-day period	10	83	37	—

In nature, *Vallisneria* usually remains confined to the shallow margins of ponds, seldom occurring at depths greater than one meter. Postmonsoon recession of water in ponds causes fatal exposure of plants about the edge of the water. However, by means of their efficient vegetative propagation, the plants maintain a population in the shallow margins of ponds through a downward migration in harmony with the receding water level, until the sexual cycle is completed. Then, upon the advent of summer, the leafy parts decay everywhere while the subterranean rhizomatous parts perennate, provided the ponds do not dry. Leaves reappear from these perennating structures, and germination occurs following the monsoon rains when the water becomes clear due to settling of the suspended solids. This timing of leaf appearance and germination of seeds suggest a sensitivity of these plants to light penetration into water.

In order to determine whether germination is affected by light intensity or light duration, seeds that had been treated with concentrated sulfuric acid for three minutes were germinated in water under different light conditions during a 12-day period at approximately 30°C. The results of this experiment are given in Table 2. Germination appears to be favored by normal photoperiod but is not affected by light intensity.

TABLE 2. Percentage germination of seeds of *V. spiralis* after treatment with concentrated sulfuric acid for three minutes, under different light conditions during 12-day period, at temperatures around 30° C.

	Per cent Germination
Continuous light	26
Normal day with normal night	89
Continuous darkness	10
Diffused light in the laboratory alternating with night	81

Appearance of seedlings in nature at a particular season suggests also a possibility of temperature sensitivity. Accordingly, seeds scarified for three minutes were tested for germination at different temperatures, and the results are embodied in Table 3. The range of temperature conducive to germination of these seeds appears to be quite broad, but the optimum temperature was found to be around 30°C. This compares quite well with the pond temperature. In ponds this temperature is attained twice a year, once in the spring and once in fall. However, optimal temperature during spring is of little value to these plants because subsequent summer desiccation kills the seedlings. In permanent ponds also, germination at this time of the year is of no benefit, because the receding water level causes death of the tender seedlings before they become mature enough to start vegetative propagation. Thus, the appearance of seedlings in fall in this region reflects the best possible adaptation of the species to the environment.

TABLE 3. Percentage germination of seeds of *V. spiralis* after treatment with concentrated sulfuric acid for three minutes, under different conditions of temperatures.

	Temperatures in Degrees C.						
	10	20	26	30	35	40	45
Maximum per cent germination in 12-day period	0	0	22	97	92	60	0

In Varanasi, the pond waters supporting *Vallisneria* populations have a pH range of 7.5 to 8.2. This alkalinity is due to high calcium levels. In other parts of the world[1] where these plants have been reported to occur, the waters have been known to be neutral to alkaline. The germination behavior of the species was tested under different pH conditions, with the pH controlled by use of buffers of suitable range. Table 4, in which the results of this experiment are presented, shows that pH of the medium, in addition to temperature, can be an important factor playing a significant role in controlling the geographical distribution of this species.

TABLE 4. Percentage germination of seeds of *V. spiralis* after treatment with concentrated sulfuric acid for three minutes, under different pH conditions of the medium, at 30° C.

	pH of the Medium							
	3	5	6	7	7.5	8	9	10
Maximum per cent germination in 12-day period	0	0	20	55	70	89	4	0

[1] Information obtained through personal correspondence with persons in different parts of the world.

Flowering

In Varanasi, *Vallisneria* usually starts flowering in November, with the first flowering observable in ponds which are slightly shaded by trees or some other structures along the banks. Winter flowering suggests dependence on shorter days and lower temperatures associated with winter months.

Seedlings germinated in the laboratory were transferred to earthen pots containing a thin layer of pond mud with water above. Photoperiods of varying lengths were given to these plants. Photoperiods longer than eight hours were obtained by supplementation of daylight with electric lamps of 100 watts suspended at a height of four feet from the water surface. Photoperiods shorter than 10 hours were obtained by covering the pots with rubberized cloth covers. The results of these experiments are given in Tables 5 and 6.

TABLE 5. Flowering, vegetative propagation, and fruit development in *V. spiralis* under different photoperiods at an average nyctotemperature of 8° C, and an average day temperature of 21° C. Each figure is a mean value for 10 plants, based on 40 individuals.

	Photoperiods in Hours						
	4	6	8	10	12	16	24
Number of female plants developing flowers	0	0	2	75	51	0	0
Number of male plants developing flowers	0	0	1	53	46	0	0
Number of plants developed vegetatively	0	0	32	301	57	0	0
Number of fruits developed	0	0	13	456	200	0	0

Flowering appears to be conditioned by photoperiod as well as by temperature conditions. During winter months a combination of low temperature and short photoperiods induces flowering (Table 5). In summer months both high temperature and long photoperiods prevent flowering. Under high

TABLE 6. Flowering, vegetative propagation, and fruit development in *V. spiralis* under different photoperiods at an average nyctotemperature 30° C, and an average day temperature of 38° C. Each figure is a mean value for 10 plants, based on 40 individuals.

	Photoperiods in Hours					
	3	4	8	10	12	16
Number of female plants developing flowers	0	0	10	16	0	0
Number of male plants developing flowers	0	28	33	31	0	0
Number of plants developed vegetatively	0	0	0	0	0	0
Number of fruits developed	0	0	0	0	0	0

temperature (Table 6) these plants can be made to flower weakly, but no seeds are produced. Temperature, therefore, plays an important part in fruit development. Fruit setting occurs always in winter and never in summer even under photoperiods conducive to flowering.

Annual Life Cycle

From these studies it appears that the different phases of the life cycle of *Vallisneria spiralis* are determined by the environment.

In Varanasi (India), the plant occurs in temporary as well in perennial ponds. In temporary ponds regeneration depends exclusively on seeds that germinate during the later part of the monsoon (warm and wet) season, in response to a lowering of temperature to about 30°C and a shortening of the day length. The plants in such cases behave as annuals.

In perennial ponds the plants behave as perennials, and regeneration occurs both by seeds and vegetative means. The plants that are exposed due to postmonsoon recession of water level behave as annuals and die before flowering can take place. Perennation is effected by the subterranean rhizomes that persist under water during summer months when high temperature causes death of leaves. Monsoon rains, resulting in a flow of water into these ponds from the surrounding uplands, cause a release of these perennating structures from the pond mud, whereupon they float and come to rest in the shallow marginal waters where they take root and again form the population that recedes as the pond dries.

Acknowledgement

I wish to express my sincere thanks to Professor Rexford Daubenmire for his constructive criticisms and guidance during the preparation of the manuscript for this paper.

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Abstracts of Papers To Be Presented at the 1966 Meeting of the Northwest Scientific Association

(Following are the abstracts of papers received by presstime to be presented at the 39th Annual Meeting of the Northwest Scientific Association to be held at Missoula, Montana, on April 15 and 16.)

The Effect of Season and Crown Position on the Foliar Mineral Content of Western Larch (*Larix occidentalis*)

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Western larch foliage was collected at biweekly intervals for two growing seasons, and the per cent nitrogen, phosphorus, potassium, calcium, and magnesium was determined. Variation in mineral content between tufted and single needles, crown position, and with respect to season will be presented. Comparisons will be made with similar analyses obtained from the foliage of lodgepole pine (*Pinus contorta* var. *latifolia*).

Hypogeous Fleshy Fungi in Western North America

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Hypogeous fleshy fungi are subterranean-fruiting Ascomycetes and Gasteromycetes. Though mostly small and unobtrusive, these fungi are common and important members of the mycoflora of forest soils; a particularly rich array of species grows in western North America. Over 40 of about 100 species of hypogeous Ascomycetes (truffles and related genera in Order Tuberales plus the genus *Elaphomyces*) occur in the western states; 20 are known only from western collections. Western hypogeous Gasteromycetes embody even greater variety and uniqueness, as illustrated by recently monographed genera. Twenty-three of 29 species of *Martellia* recognized worldwide have been found only in the West; 8 of the 11 *Gymnomyces* species, 7 of 13 *Elasmomyces,* 3 of 4 *Chamonixia,* both *Truncocolumella,* and a great majority of the more than 100 *Rhizopogon* species are similarly restricted so far as now known.

These fungi are evidently disseminated by mammals and insects rather than by wind since their spores mature underground and are not forcibly discharged. Fruiting bodies of many produce penetrating odors that attract small mammals that dig them up with zest. Most species probably form ectotrophic mycorrhizae with woody plants, as confirmed for several species of *Rhizopogon* by laboratory experiments with isolates grown with conifer seedlings in aseptic culture. Beyond this, the ecology of hypogeous, fleshy fungi is poorly known. Anyone who finds them can contribute valuably by sending specimens to a qualified taxonomist with detailed notes on color, size, odor, other distinctive characteristics of fresh specimens, the habitat in which they occurred, and the woody plants under which they grew.

The Relationships between the Ellensburg and Ringold Formations in the Pasco Basin[1]

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Final solution of the Ellensburg-Ringold Formations relationships now appears most nearly possible through the regional geologic history.

Downwarping of south-central Washington was under way by late Miocene time. Basalt flows, emanating from northern Oregon, repeatedly flooded the basin and kept pace with downwarping. The oldest Ellensburg Formation sediments formed sheetlike deposits extending eastward into the basin where they interfingered with the basalt flows.

Anticlinal uplift began in earliest Pliocene time, concomitant with less frequent outpouring of basalt flows and greater emission of volcanic debris of the Ellensburg Formation sediments. These sediments accumulated in the synclinal valleys, in places burying the anticlinal ridges. The Columbia River, flowing southwestward east of Yakima, was diverted farther eastward as flow emission decreased, the basin continued to subside, and the Ellensburg fans accordingly grew eastward. Lowermost Ringold Formation beds were deposited in quiet water east of the main Columbia River simultaneously with deposition of some of the Ellensburg Formation farther west. Downwarping of the basin, especially along north-south axes, and the continued rise of the Horse Heaven Hills further ponded the Columbia River, which continued to flow over those low hills, however. More widespread deposition of the Ringold Formation sediments and consequent overlap or transgressive relationships resulted from the increasing closure of the basin.

Erosion of Wallula Gap was speeded by the steeping dip on the south limb of the fold. As base level lowered in spite of continued rise of the anticline, by mid-Pleistocene time much of the Ringold Formation had been removed by the Columbia River flowing west of its current course, and a widespread angular unconformity was created. Further scouring of the Formation in latest Pleistocene and early Recent times by the glacial meltwaters and floodwaters immediately preceded deposition of the scabland gravels, glaciofluvial deposits, and Touchet beds.

The indicated history of the Pasco Basin is of a long period of essentially continuous evolutionary development. The major hiatus of deposition appears to lie between Ringold time and the deposition of the glaciofluvial deposits.

Basining and anticlinal uplift appear to be still under way.

The Distribution of "Intracanyon" Basalt Flows in the Snake River Canyon, Washington, between Mile 41 and 86: an Attempt To Verify a Textural Method of Distinguishing the "Intracanyon" Basalt

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The term "intracanyon" has been applied to lava flows that lie disconformably upon Yakima basalt in the Snake River Canyon of Washington and Idaho. They extend

[1]This abstract is based on work performed under United States Atomic Energy Commission Contract AT(45-1)-1830. Permission to publish is gratefully acknowledged.

discontinuously from mile 41 in Devils Canyon to about mile 155, south of Asotin, Washington.

While studying the intracanyon flows between Monumental Dam site and Central Ferry, Washington, it was found that textural criteria, particularly of the opaque fraction, provide a reliable means of distinguishing intracanyon flows, thus supplementing the conventional stratigraphic methods.

Applying all these criteria, basalt of the "intracanyon" type was identified outside of the Snake River Canyon, suggesting that the term "intracanyon" is not particularly appropriate. A more suitable term is "Late Yakima," because the "intracanyon" basalt resembles the Late Yakima, described by Waters as occurring chiefly along the Columbia River between Wenatchee and Pasco, Washington. The resemblance is in composition, texture, and disconformable relationship to the older Yakima Basalt.

Invasion of Subalpine Meadows by *Abies lasiocarpa* in the Mount Rainier Area

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Flower-rich, subalpine meadows and interspersed islands of trees provide an attractive landscape for recreationists in Mount Rainier National Park and the adjacent Cascade Range. Observed large-scale invasions of these meadows by conifers prompted a study to determine more about their extent and character.

Detailed study of a two-acre tract of subalpine meadow and forest at 5500 feet in Paradise Valley showed that meadow invasion by subalpine fir (*Abies lasiocarpa*) is very extensive and does not depend on protecting influences of adjacent forest or islands of older trees. Age determinations of 40 seedlings and saplings, ranging in height from 6 inches to 11 feet, showed about 90 per cent of the invading trees were between 30 and 48 years old; none younger than 18 years or older than 48 years were found in this area.

A wide-ranging reconnaissance of Paradise Valley and other parts of Mount Rainier National Park and of the Goat Rocks Wilderness indicates intensity of invasion (numbers of seedlings) and rate of seedling growth following establishment is related to the type of meadow community invaded. Meadows dominated by *Vaccinium deliciosum* and *Phyllodoce empetriformis* appear to be most subject to invasion.

This invasion of subalpine meadows should not be confused with reclamation of fire-created openings in high-elevation forests or with gradual expansion of forest and islands of trees onto meadows. It is a massive invasion of sites apparently not forested since glacial times, and, unless removed, growth of established trees will eliminate part or all of many meadows. The most logical explanation of invasion is a temporary amelioration of environmental conditions, probably climatic, between 1917 and 1935.

Miocene-Pliocene Formations of South-Central Washington

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Stratigraphic sections in the Horse Heaven Hills exemplify the general sequence in the Yakima-Wallula Gap-Maryhill area:

Ellensburg Formation

Wenas Basalt
Upper Member
Prosser Member
Lower Member
Selah Formation
Yakima Basalt
Priest Rapids Basalt Member
Upper flows
Mabton interbed
Basal flows
Roza Basalt Member
Frenchman Springs Basalt Member — base not exposed.

Previous studies (Laval, 1956, 1957, 1958) and subsequent field work substantiate this framework. Yakima Basalt (Smith, 1903) member designations follow Mackin's (1961) principals, but details vary from his Priest Rapids-Vantage composite section. The supra-Priest Rapids formations are correlatives of Mackin's Ellensburg Formation members. Near Yakima, the Wenas Basalt, the key formation, is Smith's Wenas Basalt of the lower Wenas Creek valley, i.e., Mackin's and Waters' (1955) Wenas Basalt and its equivalent, Waters' Elephant Mountain Basalt. Elsewhere one or two basalt units appear consistently above the Priest Rapids.

Age and Growth of Rainbow Trout in Four Alpine Lakes

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Growth-increments condition, factors, and food habits of populations of rainbow trout from four alpine lakes are compared over a period of four years. These fish were planted as fingerlings in lakes containing established brook trout and cutthroat populations. Differential growth of the rainbows from the four waters is related to carrying capacity. Spawning success and winterkill are also discussed.

Flame Retardant Wood by In Situ Radiation Polymerization of Organophosphorus Monomers

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While only one of the seven unsaturated phosphorus compounds chosen in this study was found to polymerize satisfactorily in a Co-60 source, all but one could be made to polymerize to a soft gel after 5 per cent of a crosslinking monomer was added. This possibility of increasing radiation polymerization activity by the addition of a bifunctional monomer was noted in an earlier study of the authors (Forest Prod. J., 15(7), 260(1965)), where the polymerization rate of styrene was increased by the addition of divinylbenzene.

Wood samples impregnated *in vacuo* with any of these polymerizeable mixtures, and subjected to gamma rays, showed flameproofing properties in the crib test. The chars remaining after combustion represented up to 58 per cent of the original impregnated wood, and contained only 40 to 75 per cent of the originally present

phosphorus. Wherever chlorine was part of the impregnating resin, almost none had remained in the char. All chars showed the original structure of the wood with the cells empty. These chars must possess excellent heat-insulating properties.

Impregnated wood samples which had undergone the water leaching for 14 days still showed unchanged flame resistance after drying. Since some oozing of the resin out of one of the impregnated blocks had taken place during the leaching period, it may be concluded that the resin contents of the wood samples were originally considerably above those required for the development of flame resistance.

Studies presently in progress aim at variation, as well as drastic reduction in the amounts of incorporated organophosphorus monomers, the addition of other mono- as well as bifunctional monomers in varying ratios, and attempts to increase the degree of polymerization of these monomers inside of the wood in order to improve the rheological properties of the incorporated resins; and determination of the dimensional stabilities of such preparations on exposure to water.

Herbicide Sprays Fail To Insure Prescribed Burning Success in a North Idaho Brushfield

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Moscow, Idaho

The effectiveness of seven different herbicide treatments in preparing brush for burning and subsequent tree planting was compared on a 225-acre brushfield in northern Idaho. "Tordon 101"[1] applied aerially at a one-gallon-per-acre rate in June gave an apparent first-year kill more than three times greater than that of a 2,4-D and 2,4,5-T mixture. This was as good as achieved by heavier "Tordon" applications or by dormant spray followed by a foliage spray. Susceptibility of brush species to treatments varied greatly. Because of an unusually wet summer, success of prescribed burning was influenced more by drying conditions associated with aspect than by the amount of dead brush.

Thinning and Fertilization Increase Growth in a Western White Pine Seed Production Area

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Thinning and fertilization treatments were applied to plots in a 40-year-old western white pine stand selected for seed production purposes in northern Idaho. During the four years following treatment, diameter growth of trees thinned to 20-foot and 30-foot

[1]Dow Chemical Company registered trademark for a formulation of 4-amino-3,5,6-trichlor-opicolinic acid ("Tordon") and 2,4,-D. The use of trade names is solely for identification and does not imply endorsement by the U.S. Department of Agriculture or the Forest Service.

spacings averaged 39 per cent greater than the growth where no thinning was done (9-foot spacing). Fertilization by N and NPK did not affect diameter growth in unthinned areas, but both caused a further 36 per cent growth increase where thinning had been done. Height growth was not affected by any of the treatments.

Analysis of Vegetation on Glacial Moraines in the Blackfoot Valley, Montana

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During the summer of 1965 eight exposures plus moraine mound crests on each of five mounds located in the upper Blackfoot Valley, near Ovando, Montana, were subjected to vegetational analysis. The upper and lower portion of each exposure, on each mound, was treated as a separate sampling unit, resulting in a total of 85 stands. The vegetation was studied with 20, 20 x 50 cm quadrats; Daubenmire's canopy-coverage method was generally employed. Soil-moisture readings were recorded at approximately two-week intervals between June and August. Soil temperature, above and below the surface, was also taken. Soil samples collected were analyzed for various physical and chemical properties.

The quadrat data were plotted on target diagrams after those devised by Ayyad and Dix; the resulting patterns indicate a clear relationship between species distribution and exposure. Soil-moisture conditions on the various exposures are thought to be of the greatest importance in determining distributional patterns. Individual amplitudes of tolerance, as reflected in these target diagrams, are different for each species, and range from species which are nearly ubiquitous and found on all exposures to species which are narrowly confined to specific exposures.

A Vegetational Comparison Study of Unit and Razz Lakes in the Wallowa, Northeastern Oregon

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The vegetation of Unit and Razz lakes in the Wallowa Mountains of northeastern Oregon was studied during the summer of 1964 to determine the vascular species present and the ecological and vegetational similarities between the two lakes.

Forest tree composition was determined by the transect method. The basal area per tree, density, and abundance percentage were determined. The tree composition at Unit Lake indicated an early establishment of Engelmann's spruce, followed by alpine fir and lodgepole pine. Whitebark pine, a seral tree, was common at Razz Lake, but alpine fir was more abundant. The *Vaccinium scoparium* union was dominant in the herb layer at Unit Lake, and the *Phyllodoce empetriformis* one at Razz Lake. The *Picea engelmannii-Abies lasiocarpa / Vaccinium scoparium* association was dominant at Unit Lake, and the *Picea-Abies / Phyllodoce empetriformis* at Razz Lake.

The forbs *Dodecatheon alpinum, Mitella pentandra, Pedicularis racemosa* var. *alba, Potentilla flabellifolia,* and *Senecio subnudus* were very abundant at each lake, while sedges were dominant along the lake edges. The shrub *Ledum glandulosum* was very abundant along the lake edges.

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Volume 40, No. 2, May 1966

CONTENTS

A Note on the Clay Mineralogy of Four Samples from the Ringold Formation. *C. D. Moodie, R. Okazaki, H. W. Smith, and J. A. Kittrick* 43

Soil Development over a Hearth in Willamette Valley, Oregon. *Frank F. Reckendorf and Roger B. Parsons* 46

Using Soil Series To Predict Site Index and Wood Specific Gravity in Western Montana. *T. C. Carlson and T. J. Nimlos* 56

Tidal Currents in Yaquina Bay. *Victor T. Neal* 68

Muscular Degeneration Produced by Experimental Transport Stress in Pigs. *Norman L. Adel* 75

A Painted Turtle (*Chrysemys picta*) with Ulcers in the Stomach and Duodenum. *Gilbert B. Pauley and Douglas L. Robberson* 79

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A Note on the Clay Mineralogy of Four Samples from the Ringold Formation[1]

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THE RINGOLD Formation is a prominent geologic feature of central Washington (Merriam and Buwalda, 1917; Culver, 1937; Strand and Hough, 1952; Newcomb, 1958; Brown and McConiga, 1960; Brown and Brown, 1961). The White Bluffs area extending from Richland northward to Wahluke, along the Columbia River, includes the type location. These unconsolidated sediments of Pleistocene Age extend north and east from the White Bluffs, but are covered by younger sediments in much of that portion of the Columbia Basin that is being developed for irrigation (Gilkeson, 1958).

A special clay mineralogy can be inferred from the fact that material from pits dug into the Ringold Formation has been used by the U.S. Bureau of Reclamation to line canals in Block 20 of the Columbia Basin Irrigation Project. Four samples of horizons within the Ringold Formation were used to assay the clay mineral assemblage.

Sample 1 was collected at an elevation of 550 feet, from the site described by Strand and Hough (1952), in the NE ¼, SW ¼, Sec. 2, T. 13N., R. 27E., W.M. It was from a massive clay and silt horizon near the top of the bed, and beneath a thick series of well-bedded silts containing many concretions.

Sample 4 was collected at an elevation of 565 feet, from a site in the NE ¼, SW ¼, Sec. 1, T. 10N., R. 28E., W.M. It was from a distinctive white horizon, hard and massive, 4 to 5 feet thick. This horizon along with those immediately above and below it closely resembles horizons 601-580 in geologic section A described by Newcomb (1958: 331).

Sample 9 was collected at an elevation of 626 feet, from a site in the S ½, SW ¼, Sec. 25, T. 11N., R. 28E., W.M. It was from a horizon similar in gross morphology to that yielding sample 4.

Sample 22 was collected at an elevation of 715 feet, from a site along the Mesa-Ringold road, in the NE ¼, SW ¼, Sec. 11, T. 12N., R. 28E., W.M.

[1] Scientific Paper No. 2750, College of Agriculture, Washington State University, Pullman, Washington. Work done under Project 1653.

TABLE 1. CLAY MINERALS IDENTIFIED IN FOUR SAMPLES FROM THE RINGOLD FORMATION

	Clay Minerals in Size Separates*		
Sample	$<0.2\mu$	$0.2\text{-}2\mu$	$2\text{-}5\mu$
1	M	M, I, (Ch, K)	M, I, (Ch, K)
4	M	M	M
9	M, (Ch)	M, I, K, Ch	I, K, M, Ch
22	M	M, I, Ch, K	M, I, K, Ch

* Ch = chlorite, I = illite, K = kaolinite, and M = montmorillonite. The order of listing was determined by the magnitude of the peaks on the X-ray trace. Parentheses are used if the identification was in doubt, or the peak magnitude was small.

These samples were freed of organic matter and iron, and size-separated (Kittrick and Hope, 1963). The separates were then calcium-saturated, glycerated, and examined by X-ray diffraction. Minerals with 18A spacings were recorded as montmorillonite, and those with 10A spacings as illite. Samples showing 14A and 7A spacings were potassium-saturated, and X-rayed after being heated to 400°C (to eliminate a 14A peak if it were due to vermiculite) and to 500°C (to eliminate a 7A peak if it were due to kaolinite). The results are summarized in Table 1; such minerals as quartz and feldspars are not listed.

Samples 1, 9, and 22 are similar in mineralogy with montmorillonite dominant, but associated with illite, chlorite, and kaolinite. Sample 4 has montmorillonite as the only clay mineral. The presence of montmorillonite in these horizons of the Ringold Formation seems to explain the suitability of the material used by the Bureau of Reclamation for lining canals.

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We thank R. E. Brown, HLO, General Electric Company, now with Battelle Pacific Northwest Laboratories, Richland, Washington, for collecting and describing samples 1 and 22.

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Soil Development over a Hearth in Willamette Valley, Oregon[1]

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BECAUSE TIME is one of the more difficult soil-forming factors to evaluate, soil studies are needed where soil profiles can be accurately dated. A location for such a study was found, in the form of a buried hearth, exposed in the cutbank of the Luckiamute River, Willamette Valley, Oregon (Figure 1).

Literature Review

Two studies evaluating time as a soil-forming factor are those of Simonson (1960) and Parsons *et al.* (1962). Simonson (1960) made a comparison between the loess-derived Monona soil profile and alluvium-derived soils in western Iowa as a basis for evaluating soil formation over time. Soil-forming processes expressed in the alluvium-derived soils in a period of less than 1800 years included the formation of a "genetic A1 horizon," a reorganization of free iron related to natural drainage, leaching and the development of acidity, and structure formation. As profile development of the alluvial soil was very similar to the development of Monona series, Simonson (1960) concluded that time is a less "critical factor" in the genesis of alluvium-derived soils than previously considered.

Parsons *et al.* (1962) concluded that A1 horizons in Indian mounds can form in a period of 1000 years in Iowa and are equivalent to A1 horizons of Gray Brown Podzolic soils from the adjacent landscape. Several other writers (Crocker and Major, 1955; Simonson, 1959) have also concluded that A1 horizons form quite rapidly and that organic matter gains exceed losses for a time after horizon differentiation commences. Crocker and Major (1955) have shown that soil nitrogen and carbon accumulate rapidly in the surface horizons and then gradually extend downward with increasing age. Under deciduous forest in northeastern Iowa, A2 horizons are well expressed within 2500 years, and color and structural B horizons with evidences of clay illuviation develop within 1000 to 2500 years (Parsons *et al.*, 1962).

[1] Technical Paper No. 2040, Oregon Agricultural Experiment Station, Corvallis, Oregon.

Geographic Setting

The hearth site is approximately one mile upstream from the junction of the Luckiamute and Little Luckiamute rivers in the SE ¼, SE ¼, Section 16, T.9S., R.5W. (Figure 1). The hearth occurred within the lowest terrace deposit of the Luckiamute River, which is a recently recognized (unpublished USDA data, Soil Survey Investigations, Soil Conservation Service, Corvallis, Oregon) intermediate level between the high terrace and the floodplain of the Willamette River. As yet, no soil series have been established for this level.

Local bedrock consists of folded micaceous sandstone and siltstone of the Late Eocene Spencer Formation (Baldwin, 1964). Upstream from the hearth location, the drainage basin is underlain by Eocene to Miocene igneous and sedimentary rocks (Baldwin, 1964; Vokes, 1954).

The area has a temperate climate with rainy winters and dry summers. The average annual precipitation is 51 inches, with an average annual tem-

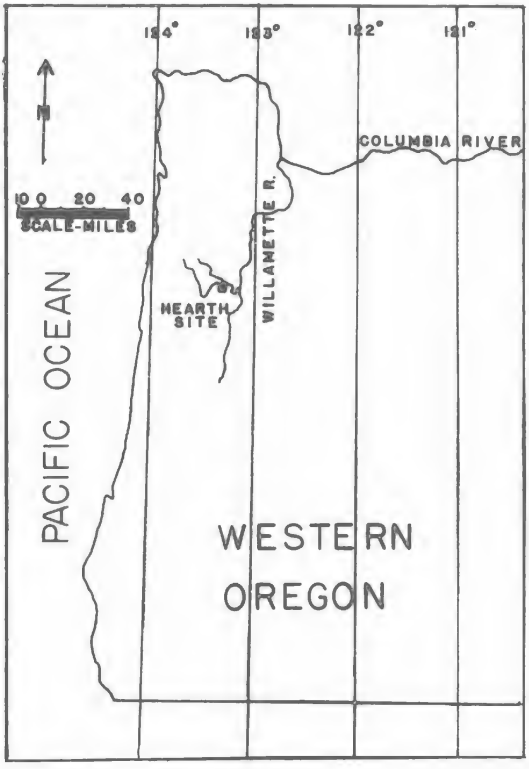

Figure 1. Index map.

perature maximum and minimum of 64°F and 39°F, respectively (Johnsgard, 1963).

The vegetation in the area is predominantly Oregon white oak (*Quercus garryana*), Douglas-fir (*Pseudotsuga menziesii*), and bigleaf maple (*Acer macrophyllum*). Some of the forested land has been cleared and is planted with small grains.

Methods and Materials

The excavation of the hearth site was carefully conducted to insure that the bank would not collapse into the river 6.1 meters below. A scaffold was erected to retain materials which would fall from the bank face. A trench, one and one-half meters by nine-tenths meter, was made behind the hearth so it could be studied from the surface. The excavated soil was examined for possible artifacts. The soil profile was described *in situ* using standard soil terminology (Soil Survey Staff, USDA, 1960). Charcoal for radiocarbon dating, rock specimens, and soil clods for thin section preparation were collected. Bulk soil samples were taken by horizon. The hearth was excavated in June, 1964, and its location was destroyed by the Luckiamute River during the late December flood of 1964.

Total carbon was determined by the gravimetric dry combustion method of Young and Lindbeck (1964) using 40-mesh soil. The extractable bases were leached with 1N NH_4 OAc and determined by flame photometry. Exchange capacity was determined by replacing NH^+_4 with HC1, distilling in a Kjeldahl flask, and titrating with 0.1N H_2SO_4 (Alban and Kellogg, 1959). Soil pH was obtained with a Beckman[2] Zeromatic instrument on a 1:1 soil-water suspension. Total nitrogen was determined by a Kjeldahl method (Alban and Kellogg, 1959).

A pipette method described by Kilmer and Alexander (1949) was used in the particle-size analyses employing sedimentation times calculated from the nomograph by Tanner and Jackson (1947). All data (Table 1) represent the average of duplicate determinations.

Results and Discussion

Soil Morphology

A11 horizon, 0-8 cm. Dark-brown (7.5YR 3/2)[3] sandy loam; massive; friable; clear wavy boundary.

A12 horizon, 8-36 cm. Dark-brown (7.5YR 3/2) loam; massive; friable; an iron bar was found at 23 cm.; abrupt irregular boundary.

[2] Trade or company names are included to provide specific information and do not imply any endorsement by the U.S. Department of Agriculture.

[3] Munsell soil colors, moist soil.

TABLE 1. PARTICLE SIZE AND CHEMICAL DISTRIBUTION DATA BY HORIZON FOR THE LUCKIAMUTE HEARTH SITE

		Percentage of size separates							
Horizon	*Depth (Centimeters)*	*VCS 2-1 (mm)*	*CS 1-0.5 (mm)*	*MS 0.5-0.25 (mm)*	*FS 0.25-0.10 (mm)*	*VFS 0.10-0.05 (mm)*	*Silt 0.05-0.002 (mm)*	*Clay 0.002 (mm)*	*Clay/Sand*
All	0-8	0.10	0.51	3.83	31.38	24.97	23.23	16.00	0.26
A12	8-36	0.07	0.30	2.43	20.02	21.18	35.33	20.67	0.47
IIA3b	36-64	0.03	0.07	0.18	1.81	9.15	54.62	34.14	3.04
IIB21tb	64-89	0.09	0.19	0.30	1.67	4.50	56.07	37.16	5.48
IIB22tb	89-109	0.05	0.12	0.31	1.29	3.31	53.37	41.55	8.18
IIIB3tb	109-153	0.03	0.32	0.39	0.93	4.10	58.49	35.73	6.18
IVC	153-214	0.03	0.07	0.11	0.50	1.65	54.17	43.53	18.92

Horizon	*Depth (Centimeters)*	*pH*	*Ca*	*Mg*	*K*	*Na*	*CEC*	*Total Bases*	*% Base Saturation*	*Ca/Mg*	*C (%)*	*N (%)*
			(milliequivalents/100g)									
All	0-8	5.5	9.5	4.4	0.3	0.1	21.5	14.3	66.5	2.2	1.66	0.12
A12	8-36	5.5	10.6	5.2	0.3	0.1	23.6	16.2	68.6	2.0	1.29	0.11
IIA3b	36-64	5.4	12.9	6.8	0.3	0.1	29.3	20.1	68.6	1.9	1.32	0.11
IIB21tb	64-89	5.4	12.6	7.2	0.3	0.2	28.8	20.3	70.5	1.8	1.06	0.09
IIB22tb	89-109	5.4	14.6	8.3	0.3	0.2	30.4	23.4	77.0	1.6	0.79	0.08
IIIB3tb	109-153	5.5	15.7	9.6	0.3	0.2	30.3	25.8	85.1	1.6	0.54	0.06
IVC	153-214	5.6	17.6	10.8	0.4	0.3	32.1	29.1	90.7	1.6	0.52	0.06

IIA3b horizon, 36-64 cm. Dark-brown (10YR 3/3) silty clay loam; weak medium prismatic breaking to moderate medium subangular blocky structure; firm; common light-gray (10YR 7/2) grainy coatings on thin discontinuous dark-brown (10YR 3/3) clay films in pores and on peds; clear wavy boundary.

IIB21tb horizon, 64-89 cm. Dark-brown (10YR 3/3) silty clay loam; weak medium prismatic breaking to moderate medium subangular blocky structure; very firm; common light-gray (10YR 7/2) grainy coatings on thin discontinuous dark-brown (10YR 3/3) clay films in pores and on peds; clear wavy boundary.

IIB22tb horizon, 89-109 cm. Dark yellowish-brown (10YR 3/4) silty clay; weak medium prismatic breaking to moderate medium subangular blocky structure; firm; few light-gray (10YR 7/2) grainy coatings on thin continuous dark-brown (10YR 3/3) clay films in pores and on peds; gradual wavy boundary.

IIIB3tb horizon, 109-153 cm. Dark yellowish-brown (10YR 4/4) silty clay loam; weak medium prismatic breaking to weak medium subangular blocky structure; firm; few fine distinct dark-brown (7.5YR 4/4) mottles; few light-gray (10YR 7/2) grainy coatings on thin continuous dark-brown (10YR 3/3) clay films in pores and on peds; clear wavy boundary.

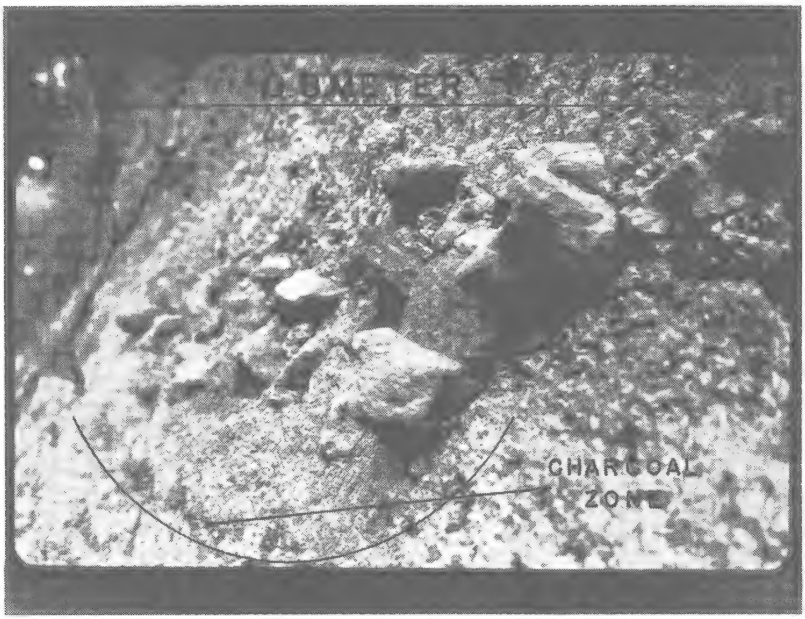

Figure 2. Prehistoric hearth.

Hearth, 109-150 cm. Approximately 250 fired, red (2.5YR 5/8) subrounded (Pettijohn, 1949) pieces of friable micaceous sandstone and siltstone, having a maximum diameter of 18 cm. and an average diameter of 7 cm., arranged in a semicircular hearth (Figure 2). These rocks were coated with thick, continuous, dark-brown (10YR 3/3) clay films. Three subangular pieces of quartz diorite, one rounded piece of basalt, and one rounded piece of diabase were also in the hearth. These igneous rocks were coated with thin clay films.

The interstitial soil was burned brown and light brown (7.5YR 5/4 and 6/4) silty clay; with weak medium prismatic breaking to weak fine subangular blocky structure. Abundant charcoal was dispersed throughout the hearth, but no artifacts were found. Charcoal from the base (148-150 cm.) of the hearth (Figure 2) was dated by C^{14} methods at 5250 $\pm$ 270 years B.P.[4] The charcoal extracted from the hearth was identified as Douglas-fir (*Pseudotsuga menziesii*) and bigleaf maple (*Acer macrophyllum*). Five charred acorns were found in the hearth at various depths, but no positive identification has been made beyond the genus *Quercus.*

IVC horizon, 153-214 cm. Dark-brown (10YR 4/3) silty clay; massive; common fine distinct dark-brown and strong brown (7.5YR 4/4 and 5/6) mottles; thin discontinuous dark-brown (10YR 3/3) clay films along fractures; occasional fine manganese oxide segregations; clear wavy boundary.

Laboratory Results

Particle size and chemical data given in Table 1 indicate several discontinuities in the profile. The upper discontinuity was identified as postcultural by an iron bar found at 23 cm. Changes in texture, cation exchange capacity, and total bases at 36 cm. further substantiate this discontinuity. The hearth indicates the discontinuity at 109 cm. Since the hearth occupies a very small area, morphologic identification of the discontinuity at other locations would be most difficult. A discontinuity at 153 cm. is indicated by changes in field texture, very fine sand and silt fractions, and total bases. The clay-sand ratio also exhibits an abrupt change at this depth.

Discontinuities in the profile make it difficult to distinguish soil properties which may have resulted from pedogenesis from those properties inherited from the presumed parent material. However, soil structure and clay films are morphologic features which are clearly pedogenic.

Clay translocation in the soil profile is evidenced by clay films on B horizon ped surfaces, observed in the field and in thin section, and the well-developed clay films on the hearth rocks. Clay films over the fired rock

[4] Isotopes Inc., Westwood, New Jersey, Sample No. I-1472.

surfaces indicate that clay translocation has been subsequent to hearth construction.

The greater development of clay films on the fired surfaces of hearth rocks than on peds of the adjacent soil could be a result of better aeration porosity (as contrasted to capillary porosity) at the rock-soil contact. If this were the case, the soil would dry faster where better aerated, and clay would be precipitated and oriented from the colloidal suspension. Clay films are better expressed on the sedimentary than the igneous rocks, perhaps due to the greater porosity of the sedimentary rocks.

Grainy ped coatings in Iowa soils (Arnold and Riecken, 1964) have served as evidence of relict forest influence on Brunizems. Insufficient evidence is available about soil biosequences (White and Riecken, 1955) in Oregon to draw any conclusions as to the relict nature of grainy coatings. However, in the hearth profile, clay films increase, whereas grainy coatings decrease, with increasing depth in the solum. The occurrence of grainy coatings on clay films suggests the degradation of the solum as the IIA3b advances into the IIB21tb horizon.

The carbon content gradually decreases with depth and crosses the postcultural discontinuity at 36 cm. Table 1 shows an abrupt increase in the total bases and cation exchange capacity at 36 cm. with no corresponding abrupt increase in organic carbon or nitrogen content. Therefore, the capacity of the soil to adsorb bases below 36 cm. is primarily related to the amount and kind of clay rather than the distribution or content of organic matter.

If the carbon and nitrogen contents were largely inherited from several increments of alluvium, their depth distributions would probably be erratic, rather than showing a gradual decrease with depth. The distribution of carbon and nitrogen in the hearth profile is similar to that found in upland soils in the Oregon Coast Range. Parsons and Balster (1965) obtained carbon and nitrogen values in B and C horizons of 0.5 per cent and 0.05 per cent, respectively. These values are similar to those of equivalent horizons of the hearth profile. Riecken and Poetsch (1960) also found organic matter gradually decreased with depth in some alluvial soils in Iowa. Nitrogen values were comparable in magnitude to those obtained for the hearth soil. Thus, the carbon and nitrogen distributions in the hearth soil probably reflect postcultural accumulation, since the greatest values for carbon and nitrogen are found in the overlay.

The base data given in Table 1 indicate translocation of bases within the profile. Aside from the postcultural increment, there is an 8.4 per cent increase in base saturation between 36-153 cm. and a 22.1 per cent increase

between 36-214 cm. Below 214 cm. for the next 178 cm. there is less than 1 per cent increase in the per cent base saturation (unpublished USDA data, Soil Survey Investigations, Soil Conservation Service, Corvallis, Oregon). Therefore, leaching of bases has occurred within the solum in 5250 ± 270 years. Impeded drainage, indicated by the mottles in the lower horizons, would favor accumulation of bases in these horizons due to restricted downward water movement. A portion of the bases may, of course, be attributed to the initial content of the parent material.

The ratio of exchangeable calcium to exchangeable magnesium can also be used as an indication of soil development since the ratio narrows with increased weathering and leaching (Barshad, 1960). The wide Ca/Mg ratios in the A11 and A12 horizons reflect Ca recycling by vegetation.

Summary and Conclusions

Soil development in the Willamette Valley may attain a significant degree of expression in 5250 ± 270 years. The soil has developed in at least four terrace deposits as represented by three discontinuities. Moderate medium subangular blocky structure has formed in the B horizon within this time period. Significant quantities of clay have been translocated during this time as shown by the thick clay films which coat the fired rocks of the hearth, as well as the thin clay films on the peds throughout the B horizon.

The carbon and nitrogen distributions reflect postcultural accumulation, since the organic content is greatest above the first discontinuity. Therefore, organic accumulation is quite rapid in the study area. Some organic matter may have been incorporated with the alluvial parent materials, but if the carbon and nitrogen is inherent, then an erratic depth distribution could be expected. The gradual decrease with depth across discontinuities indicates the possible organic content of the parent material has been obscured by soil-forming processes. Leaching during soil development is probable as evidenced by the increase of bases, and the decrease of Ca/Mg, with depth.

The radiocarbon date of 5250 ± 270 years B.P., obtained from charcoal at the base of the hearth, represents the earliest evidence of human habitation in the Willamette Valley (D. L. Cole, Archaeologist, University of Oregon, personal communication, February, 1965). Stratigraphically, the date falls approximately in the middle of the Postglacial Hypsithermal (Deevey and Flint, 1957) or in the Thermal Maximum (Ruhe and Scholtes, 1956).

The radiocarbon date, in addition to indicating a maximum age for soil development, and a minimum age for human occupation, also provides a maximum time for the accumulation of 109 cm. of alluvium along the

Luckiamute River. This single date is inadequate to determine a regional rate of geologic erosion. But as additional dates from alluvial deposits in the Willamette and tributary valleys become available, a rate of geologic erosion can be established.

Acknowledgements

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Using Soil Series To Predict Site Index and Wood Specific Gravity in Western Montana[1]

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THE PURPOSE of this study was to evaluate certain soil series as criteria for predicting site index and wood specific gravity of trees growing thereon. The soils occur in western Montana where a largely forest-dependent economy lends importance to knowledge of both site quality and wood quality. Unfortunately, many forest conditions do not allow direct measurement of these factors for desirable species; two obvious examples are unstocked forest land and areas that currently support undesirable species. Therefore, indirect measurement techniques are needed—techniques that do not require the presence of a particular species to predict its probable growth rate and wood quality. The soil series may provide a basis for such prediction.

Characteristics of the soil-moisture regime are inherent in the basic concept of soil series. The soil-moisture regime also influences both site index and wood specific gravity, and, at present, these two variables appear to be the best single indicators of site and wood quality (as defined by Mitchell, 1961), respectively. Thus, factors that define a soil series also affect tree growth and wood properties. The predictive value of a soil series will depend on the strength of these interrelationships.

Four commercially important tree species were studied on five soils. The species were western larch (*Larix occidentalis* Nutt.), Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco), ponderosa pine (*Pinus ponderosa* Laws.), and lodgepole pine (*Pinus contorta* Dougl.).

Soils studied were the Cabinet, Tenibac, Selle, Waits, and Tarkio series.

Present Knowledge

The general aspects and limitations of site interpretation from soils are well documented by Coile (1958), Rowe (1962), and Zahner (1962).

Most soil-site studies have been done in the eastern United States where

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land use is relatively intensive. Investigations performed in the West indicate that various factors of the soil-moisture regime often affect tree growth significantly (Cox *et al.,* 1960; Embry, 1960; Gessel, 1950; Holmes and Tackle, 1962).

Cox *et al.* (1960) concluded that ponderosa pine productivity in western Montana may be predicted from soil-site relationships. Furthermore, in the absence of soil survey maps, growth can be predicted in this area by noting certain features such as land form and effective soil depth.

Soil moisture also apparently influences wood specific gravity (Smith and Wilsie, 1961; Paul, 1959; Wheeler and Mitchell, 1962; Larson, 1957). Wilde and Mikola (1951) reported generally higher jackpine specific gravity on sandy soils of lower site quality; because highest site index and lowest specific gravity occurred on soils that had been under the influence of podzolization, the authors assumed that the leaching process, where not too drastic, carried nutrients and organic matter into the zone of highest root activity. The evidence is not consistent, however, at least among species: Wilde and Paul (1959) reported that specific gravity of aspen in Wisconsin could not be related to soil types; they found little difference in specific gravity variation even between the highest and lowest sites.

Description of the Study Area

The study was confined to the Clark Fork valley bottom between Thompson Falls and the Idaho state line in Sanders County, Montana—an area about four miles wide by 50 miles long.

Climate. Annual precipitation varies from 20 inches at the southeast end to 34 inches at the northwest end of the study area (U.S. Weather Bureau, 1960). Mean annual temperature varies about four degrees along the valley, the average being approximately 45°F. Average length of growing season over the entire area is about 108 days.

Stand characteristics. Two forest fires, one in 1910 and the other in 1889, probably account for present species distribution and the predominance of age classes between 40 and 70 years. Some idle cleared land is in need of reforestation, and other areas support undesirable species. The remaining stands are mostly pure, well-stocked, even-aged (40 to 80 years old) ponderosa pine, western larch, Douglas-fir, and lodgepole pine. Tree vigor is generally good except that lodgepole pine stands tend to stagnate at about 35 years.

Physiography and parent materials. The valley bottom is nearly flat. Short stream-dissected terraces flank the valley, and a gently rolling, dunelike

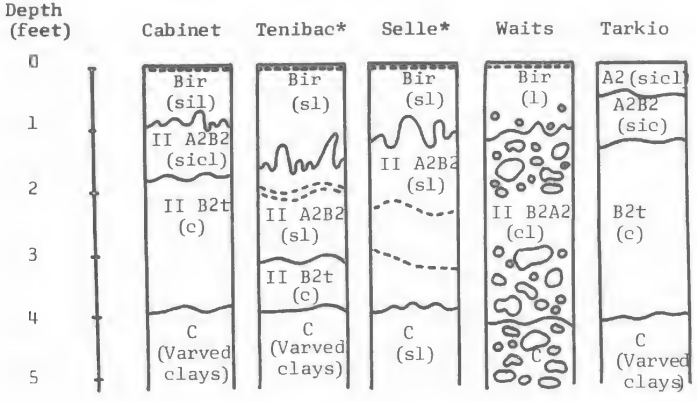
area occurs near its center. During Pleistocene, a sublobe of the Cordilleran ice sheet dammed the Clark Fork River near the Idaho state line, causing glacial Lake Missoula to be formed (Alden, 1953). Sediment, varying from fine clay to coarse sand, was deposited in the lake bed. This material forms the present valley floor, and its textural variations are evident in the strata of soils now occupying the area.

Most of the valley soils have developed in these lacustrine clays and sands and to a lesser extent in coarse stream alluvium from adjacent mountains. Some sandy and silty overburden material may be of loessial origin. A small amount of local glacial drift is present.

Soils. Four of the soil series studied are Brown Podzolic and one (Tarkio) is of the Gray Wooded great soil group; their morphologies are shown in Figure 1. The Brown Podzolics may or may not exhibit a gray, very thin, discontinuous A2 horizon above the Bir.

The Cabinet series was apparently formed in light, silty mantle material over lacustrine, varved clays. The surface horizon (Bir) varies from 6 to 16 inches in thickness. It is light, fluffy, and bright reddish-brown with many medium-sized shot. Immediately below the Bir is a thick clay horizon of strong subangular blocky structure. Varves are usually encountered at 36 to 48 inches below the surface.

The Tenibac series was formed in sandy mantles over varved clay. The surface horizon (Bir) is usually a weak-structured, light-brown, sandy loam with many fine shot. A clay horizon, between 18 and 60 inches, is usually



* *Dotted lines* indicate compact, discontinuous lenses.

Letters in parentheses are normal texture abbreviations.

Figure 1. Simplified profile diagrams of the study soils.

much the same as the clay horizon of the Cabinet series but sometimes includes stratified sands and clay. Thin lenses of heavier-textured material are often found within the sandy loam horizons and seem to have a significant effect on the moisture-retention capacity of this soil.

The Selle series was formed in deep mantles of light sandy loam. If clay is encountered at all, it is deeper than 60 inches. The entire profile exhibits weak structure and a poorly defined Bir occurs at the surface. The same type of heavier-textured lenses as in the Tenibac series (although not as common) may be found within the sandy portion of the profile.

The Waits series has a surface Bir horizon much like that of the Cabinet. Unlike the Cabinet series, however, the silty mantle of the Waits series lies over a gravelly or cobbly substrate of stream alluvium or glacial drift. Few gravels are found in the Bir, but the volume of coarse fragments in the underlying horizon usually exceeds 50 per cent. The matrix between coarse fragments is commonly sandy clay loam. Clay content seems to increase with depth.

The soil we have called Tarkio falls within the limits of the formal Tarkio description; yet, it contrasts markedly with the more commonly encountered Tarkio soil in that it has a grayish-brown A2 horizon, contains fine shot, lacks columnar structure, and is not calcareous (Personal communication, R. C. McConnell, U.S. Forest Service, Missoula, Montana). Being formed in an area of higher precipitation, the study Tarkio is apparently intergrading towards the Brown Podzolic great soil group while the formally recognized Tarkio is definitely a Gray Wooded soil.

Procedures

Seventy-seven temporary plots were established to sample, as equally as possible, each of the species-soil combinations. Criteria for plot selection included: 1. adherence to the modal concept of the series; 2. a healthy timber stand; 3. slopes less than 10 per cent; and 4. adjacent replicate plots located no closer than ¼ mile.

Plots varied in size according to proximity of sample trees and homogeneity of soil, but their radii rarely exceeded 20 feet. More than one species was sampled at a single plot site only where each exhibited at least codominance. Site quality measurements were made on a total of 645 trees; specific gravity was determined for 560 of these.

At each plot, a pit was dug to a depth of five feet and the profile described according to standard procedures (Soil Survey Staff, 1951). Total height, age and diameter at breast height, and basal area were measured on five

dominant or codominant trees of each of the study species found at each plot. Growth curves by Cummings (1937), Meyer (1938), and the British Columbia Forest Service (1947) provided bases for calculating average site indexes.

Specific gravity was computed for whole 8 mm. increment cores collected after the method described by Wahlgren and Fassnacht (1959). Compression wood was avoided by taking cores from the "tension" side of the tree and rejecting those few that showed areas of compression wood under subsequent examination.

The statistical design was based on a randomized, one-way classification for each species. Four species-frameworks were subjected to analysis of variance; each framework consisted of five "cells" that contained the observations for species-soil combinations.

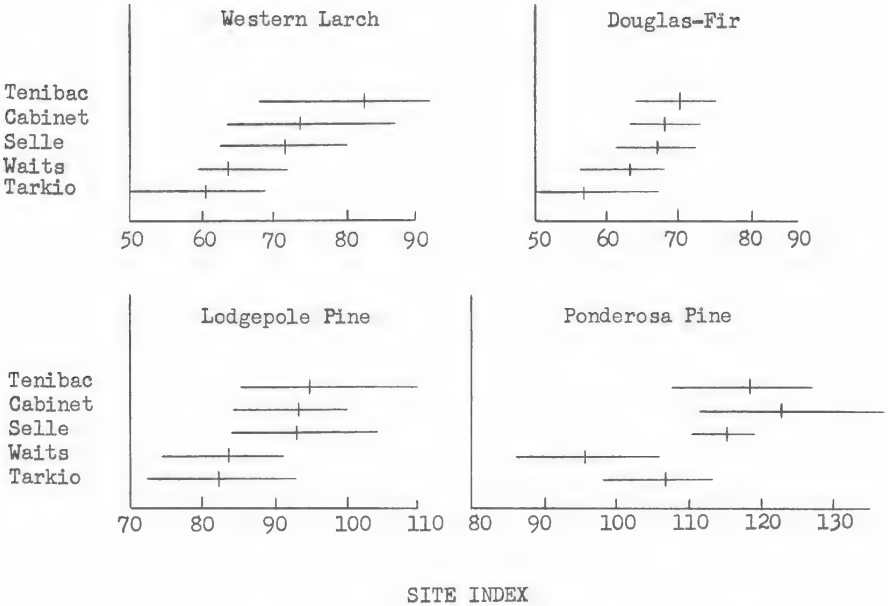
The original plan was to take an equal number of observations (replicates) in each cell, but this was found impossible in practice. The soils and stands of the study area were not equally distributed, and collection of additional data to complete those cells with few observations would have necessitated repetitious sampling. The mean, standard deviation, and standard error were calculated for each cell. Means were then compared using a modification of Duncan's multiple range test to correct for unequal observations (Steel and Torrie, 1960).

Results and Discussion

Soils develop and mature in response to many site variables; and since soils are relatively stable, their characteristics reflect long-time site conditions, some of which have immediate effect on tree development. Differences between certain soil series, then, should reveal consistent differences in tree growth and wood quality. The following analyses are intended to show the existence of these growth and quality differences and their consistent occurrence between soils, not to prove that soils cause them.

Site index and soil series. Mean site indexes for the four study species on the five soils are shown in Table 1. A graphic comparison of the means and ranges of site index (Figure 2) showed consistent differences in site index between soils. Subsequent analysis of variance and multiple range tests revealed that some of the differences were significant (at the 95 per cent level) for all species (Table 1). The highest levels of significance occurred in western larch and ponderosa pine.

Table 2 shows the range of expected site indexes (as calculated from the data in Table 1) for the various soil series and series associations. For the purpose of this paper, series "associations" are considered to be the soils on which the stands do not have significantly different site indexes. Most of them



(Horizontal line represents range - vertical line, mean.)

Figure 2. Mean values and total variation of site index by soil series.

coincide with the actual soil associations noted in the preliminary Soils Association Map for western Sanders County (U.S. Soil Conservation Service, 1964). Reasonably reliable predictions of site index should be obtained by using this map along with Tables 1 and 2.

Approximate mean site indexes on all soils were as follows: western larch, 75; Douglas-fir, 65; ponderosa pine, 115; and lodgepole pine, 95. Unfortunately these values are not comparable because each species has its own base age (larch and Douglas-fir, 50 years; ponderosa pine, 80 years; lodgepole pine, 100 years) and growth-curve shape. Noticeably poorer sites were found in other studies in which much of the remaining area in western Montana was sampled. For example, Embry (1960) found average values of 58 for larch; Cox *et al.* (1960) determined that ponderosa pine site indexes averaged about 80; and the mean for lodgepole pine, as calculated from Holmes and Tackle's (1962) figures, was 64. It appears, then, that western Sanders County contains some of the most productive timber sites in Montana.

The general order of decreasing site index by soil series was Tenibac>Cabinet>Selle>Waits>Tarkio. Ponderosa pine was the only species that

TABLE 1. DESCRIPTION OF VARIATION AND COMPARISON OF MEAN S.I.'S ON THE STUDY SOILS BY DUNCAN'S MULTIPLE RANGE TEST

Species	*Item**	*Soil***				
		Tenibac	*Cabinet*	*Selle*	*Waits*	*Tarkio*
	SE	1.57	2.72	2.64	1.73	2.95
Western	SD	6.28	8.15	6.99	4.63	7.91
larch	n	16	9	7	6	6
	$\bar{x}$	82.3	73.6	71.5	63.2	60.2
	SE	1.40	1.41	1.94	1.57	2.33
Douglas-fir	SD	3.70	3.46	4.73	4.15	6.58
	n	7	6	6	7	8
	$\bar{x}$	70.0	68.0	67.0	63.1	56.8
	SE	1.69	2.39	2.75	2.95	4.28
Lodgepole		6.96	5.85	6.74	7.22	9.58
pine	n	6	6	6	6	5
	$\bar{x}$	94.9	93.3	93.2	83.7	82.2
		Cabinet	*Tenibac*	*Selle*	*Tarkio*	*Waits*
	SE	3.11	2.42	1.23	2.07	3.13
Ponderosa	SD	9.34	7.25	3.27	6.20	7.68
pine	n	9	9	7	9	6
	$\bar{x}$	122.6	118.2	114.4	106.8	95.3

* SE = standard error
SD = standard deviation
n = number of observations
$\bar{x}$ = mean

** Soils *not* underlined by the same line have significantly different mean indexes (at the 95% level).

deviated from this sequence. The first two soils apparently had the structure and depth of surface horizon to permit active rooting, and enough fines to aid in moisture retention. The Selle series was coarse textured enough to permit good root penetration, but this characteristic also resulted in low moisture retention. The relatively low sites on Waits are undoubtedly due to the smaller effective rooting volume because of coarse fragments. In the Tarkio soil, root activity and water availability were influenced adversely by very fine texture, weak subsurface structure, and surface compactness.

Soil-site studies commonly employ about three to five plots for each series-species combination. Statistical verification of the minimum number of plots necessary to attain reasonable reliability should be helpful to those conducting

TABLE 2. RANGES OF EXPECTED (95% LEVEL) AVERAGE SITE INDEX ON THE SERIES AND SERIES ASSOCIATIONS

Species	*Series or Series* Association*	*Range of Expected Mean S.I.'s*
Western larch	Tenibac	79-85
	Cabinet-Selle	66-79
	Waits-Tarkio	54-67
Douglas-fir	Tenibac-Cabinet-Selle	63-73
	Cabinet-Selle-Waits	60-71
	Tarkio	52-61
Lodgepole pine	Tenibac-Cabinet-Selle	88-98
	Waits-Tarkio	74-91
Ponderosa pine	Cabinet-Tenibac	113-129
	Tenibac-Selle	112-123
	Tarkio	103-111
	Waits	89-102

* "Associations" are series that do not exhibit significantly different site indexes.

the studies. Therefore, the probable sample size necessary to attain certain assumed levels of variation and confidence was also calculated (Cochran and Cox, 1950). Based on the variation observed in this study and a 95 per cent level of confidence, the minimum acceptable sample is four plots. This means that the investigator should take less than four plots only if he is willing to accept less stringent limits than established herein; and for soils that exhibit wide variation in site quality, more plots should be taken.

Specific gravity and soil series. Statistical methods for analyzing gravity data were similar to those for site index (Figure 3). Analysis of variance revealed significant differences between soils for western larch and Douglas-fir specific gravity, but none for ponderosa or lodgepole pine. Table 3 describes the variation in specific gravity and shows the significantly different soils for larch and Douglas-fir. However, the common age classes were not represented equally on all soils. Certain of the soils supported trees of younger-than-average age and lower-than-average specific gravity, dependent variables that are usually correlated (Yandle, 1956). Although sufficient data for proof are lacking, the effect of soil may be misrepresented by this analysis. At any rate, use of significant differences in specific gravity between soils for reliable prediction purposes appears somewhat questionable. The seemingly soil-dependent variation indicated in the analysis of variance may be confounded by physiological tree age. Additional work is needed to substantiate this possibility.

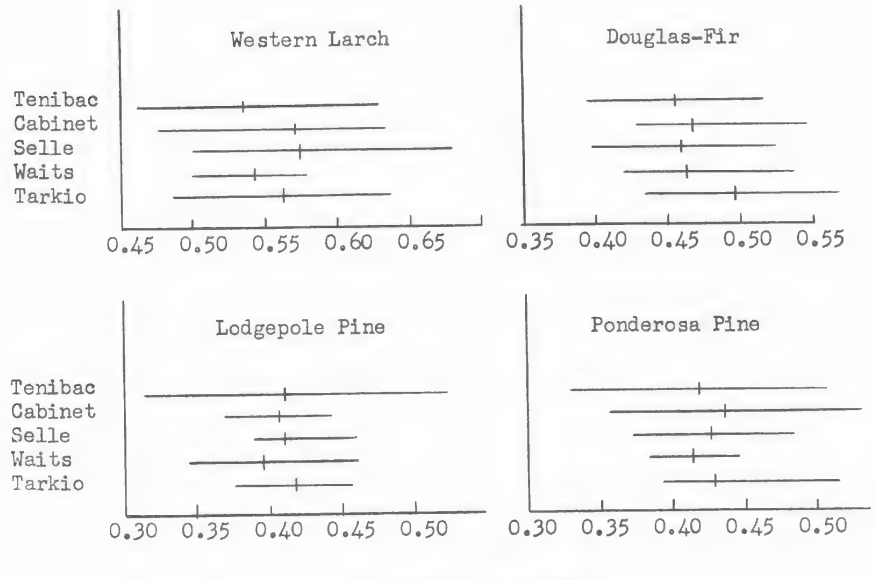


Figure 3. Mean values and total variation of specific gravities by soil series.

A possible explanation for the nonrandom distribution of age in the study area is that the soils are geographically concentrated in such a way that fires or logging occurred at about the same time on particular soil units. Another, though less likely, explanation could be that some characteristic of the soil (duff layer, moisture level, etc.), or density of pioneer vegetation, retarded germination on some soils, while regeneration followed promptly on others.

Average specific gravities of increment cores extracted for this study were compared with average values, derived by the same methods, in other investigations. Mean specific gravity for larch (0.549) was nearly identical to that (0.550) found in the intermountain region (Personal communication, D. P. Lowery, U.S. Forest Service, Missoula, Montana). Lodgepole pine specific gravity was slightly higher than Tackle's (1962) estimate for Wyoming and southern Idaho, 0.409 as compared with 0.386. Similarly, ponderosa pine specific gravity (0.427) exceeded the value determined by Conway and Minor (1961) in Arizona (0.404). And, inland Douglas-fir specific gravity in northern Idaho was calculated to be 0.428 (Personal communication, J. P. Howe, University of Idaho, Moscow, Idaho), while the value determined in this study was 0.465.

TABLE 3. DESCRIPTION OF VARIATION AND COMPARISON OF MEAN SPECIFIC GRAVITIES ON THE STUDY SOILS BY DUNCAN'S MULTIPLE RANGE TEST

		*Soil Series***				
Species	*Item**	*Selle*	*Cabinet*	*Tarkio*	*Waits*	*Tenibac*
Western larch	SE	0.014	0.009	0.007	0.005	0.004
	SD	0.051	0.039	0.036	0.023	0.035
	n	14	20	24	19	62
	$\bar{x}$	0.573	0.570	0.562	0.542	0.534
		Tarkio	*Cabinet*	*Waits*	*Selle*	*Tenibac*
Douglas-fir	SE	0.010	0.006	0.005	0.007	0.007
	SD	0.039	0.029	0.028	0.029	0.035
	n	14	23	30	18	23
	$\bar{x}$	0.496	0.467	0.463	0.458	0.454
Lodgepole pine	SE	0.006	0.007	0.006	0.013	0.005
	SD	0.025	0.027	0.030	0.030	0.038
	n	16	17	25	5	60
	$\bar{x}$	0.418	0.406	0.396	0.410	0.412
Ponderosa pine	SE	0.009	0.008	0.007	0.005	0.008
	SD	0.033	0.046	0.023	0.028	0.043
	n	14	30	10	27	28
	$\bar{x}$	0.429	0.437	0.414	0.427	0.419

* SE = Standard error
SD = Standard deviation
n = Number of observations
$\bar{x}$ = Mean

**Soils *not* underlined by the same line have significantly different specific gravities (at the 95% level).

Specific gravity, determined from increment cores at breast height, is invariably higher than the values given as averages for species over their entire range (U.S. Forest Service, 1955). Breast-height gravities would also be expected to be higher than tree averages, since higher densities are normally encountered near the ground. Therefore, the values given in this paper consistently exceed overall species averages.

Summary and Conclusions

Results of this study support the following conclusions:

1. Site indexes in western Sanders County are among the highest in Montana for the four tree species studied.

2. Average site indexes were significantly different between some soils for all species studied. The soil series, then, can be used to predict site index in the study area. On the basis of observed variation and a 95 per cent confidence level, the minimum acceptable sample for comparable soil-site studies is four plots.

3. Best tree growth was found on the well-developed Brown Podzolic soils with light-textured surface horizons over strongly structured clay (Tenibac and Cabinet series). Poorest growth was found on the Gray Wooded (Tarkio) soil and the gravelly Brown Podzolic (Waits). Stands growing on the uniformly sandy Brown Podzolic soil (Selle) exhibited intermediate site indexes.

4. Average breast-height core specific gravity of larch closely approximated the similarly derived value from other study areas, while those of inland Douglas-fir, lodgepole pine, and ponderosa pine slightly exceeded values determined elsewhere.

5. Specific gravity of larch and Douglas-fir differed significantly between some soils; that of ponderosa and lodgepole pine did not. Even where differences existed, however, the reliability of using soil series to predict specific gravity is questionable at present because of the unknown effects of tree age.

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Tidal Currents in Yaquina Bay

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A SIMULTANEOUS tide and tidal current measurement program, in conjunction with a biological study, was conducted during a complete tidal cycle, August 9 and 10, 1963, by the Department of Oceanography of Oregon State University. The stations occupied were distributed from the Coast Guard dock to buoy 45.

The range of the tide was measured visually on stick gages at the Coast Guard dock, River Bend Marina, and Criteser's Marina. An automatic portable tide gage was installed at Sawyer's Marina (Yaquina) for this period.

Tidal currents were measured from boats anchored in midchannel at buoy 21 (near River Bend Marina), buoy 29, and buoy 45 (near Criteser's Marina). The locations of all stations mentioned are shown in figure 1. It was not practical to keep a station near the entrance to the bay due to traffic. Each boat station was supplied with a TSK (Tsurumi Seiki Kosakusho Company, Limited, Yokohama, Japan) current meter, except the station at buoy 21, where a Price current meter was used.

The current measurements were taken as frequently as practicable at the surface, middepth, and bottom. The current meters suffered from such demands, and most of them became inoperable near the end of the program.

During the measurement period the wind was light except from the mouth of the bay up to Yaquina during the afternoon of August 9. During that time the wind was westerly and relatively strong in the lower reaches of the bay. No other stations were exposed to strong winds during the survey.

Results

The tide in Yaquina Bay is a mixed semidiurnal tide, which is characteristic of the California, Oregon, and Washington coasts. The observed times of high and low tide (expressed in Pacific Daylight Time) with the duration of ebb and flood are given for each tide station in Table 1. The tidal ranges, expressed in centimeters, are also listed in Table 1.

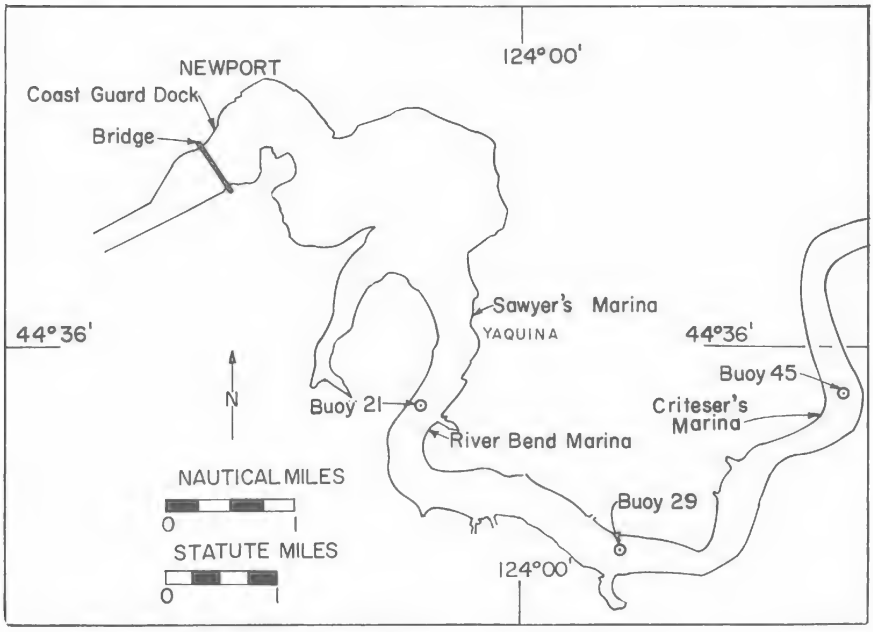

Figure 1. Yaquina Bay, showing measurement stations.

A study of these data shows that the range of the tide increases upstream, with the maximum range of 283 cm (9 feet 3 inches) occurring at the station farthermost from the mouth, Criteser's Marina. The variation in times of tide stages at the various stations was everywhere less than one hour and rarely over 30 minutes. The duration of flood was greater than the duration of ebb except at Criteser's Marina.

The tides predicted by the U.S. Coast and Geodetic Survey (1963) are also listed in Table 1. The predicted tidal ranges at times were in error as much as 19.5 per cent. The maximum actual error in range prediction was 51 cm at Criteser's Marina. The time predictions were generally good, although nearly all of them were earlier than the observed tide. In one instance an error of 34 minutes was found.

Table 2 lists the maximum surface currents recorded as well as the predicted currents (U.S. Coast and Geodetic Survey, 1963). It should be noted that the predictions were not for the stations occupied.

The observed currents (Figure 2) were quite uniform in phase from the surface to the bottom. The bottom current was always the weakest. The ebb flow was greatest on the surface at all stations and was always greater than the flood. The greatest flow rate measured was 78 cm/sec (1.5 knots)

at the surface at buoy 21. The maximum currents were observed to decrease with increasing distance from the mouth. The general current pattern was sinusoidal, being approximately 90° out of phase with the tides (Figure 3).

Slack water came no more than 30 minutes behind high or low tide while the maximum currents lagged midtide as much as one hour. The time of slack water following low tide was very uniform up and down the bay.

The times of predicted slack do not show the degree of uniformity actually observed, especially for the slack following low tide. The predicted currents do not show a consistently decreasing maximum upstream nor do they show a stronger ebb than flood at all stations. On the other hand, greater uniformity in times of maximum flood was predicted than was observed.

Discussion

If the tide arising in the ocean causes a progressive wave to enter a bay, it is generally assumed that the wave may be approximately represented by the equation:

$$\eta = \eta_0 \cos (kx - \omega t)$$

In this equation η is the surface displacement at any position x, and time t,

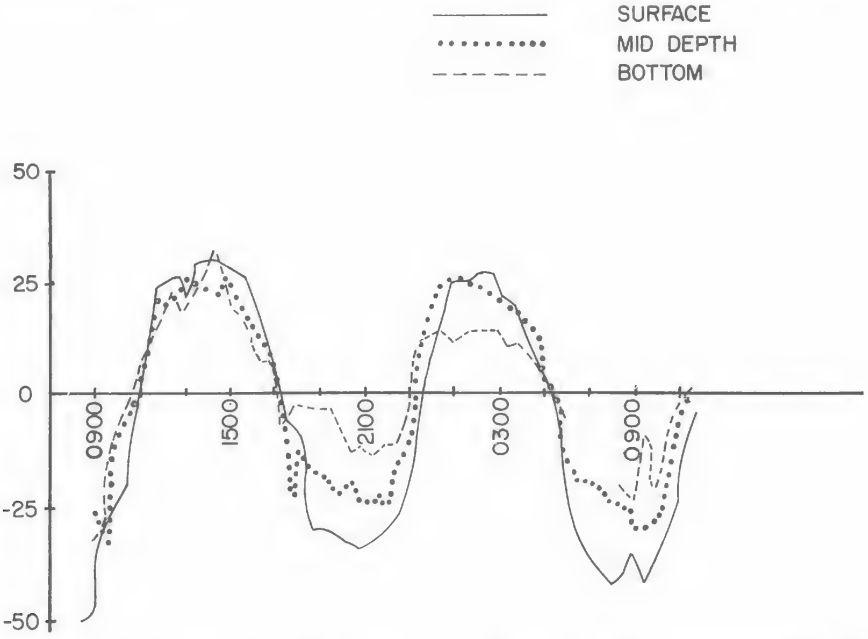

Figure 2. Currents (cm/sec) recorded at buoy 29. Flood currents are positive, and ebb currents are negative. The horizontal axis is the time in hours, based on the 24-hour clock.

TABLE 1. OBSERVED AND PREDICTED TIDAL DATA. ALL TIMES ARE PACIFIC DAYLIGHT (USING THE 24-HOUR CLOCK) AND RANGES ARE EXPRESSED IN CENTIMETERS

			ΔT *flood*				ΔT *ebb*				ΔT *flood*				ΔT *ebb*		
Station	*Low*	*High*	*hr.*	*min.*	*Range*	*Low*	*hr.*	*min.*	*Range*	*High*	*hr.*	*min.*	*Range*	*Low*	*hr.*	*min.*	*Range*
								Observed									
Coast Guard	0956	1630	6	34	262	2222	5	52	207	0440	6	18	179	1050	6	10	211
Yaquina	1030	1645	6	15	267	2245	6	00	214	0500	6	15	189	1115	6	15	217
River Bend	1000	1640	6	40	272	2240	6	00	218	0445	6	05	191	1050	6	05	220
Criteser's	1045	1700	6	15	283	2310	6	15	231	0500	5	50	200	1110	6	10	225
								Predicted									
Coast Guard	0954	1622	6	28	223	2224	6	02	177	0415	5	51	165	1036	6	21	195
Yaquina	1007	1633	6	26	229	2237	6	04	183	0426	5	49	171	1049	6	23	201
Criteser's	1028	1641	6	13	232	2258	6	17	186	0434	5	36	174	1110	6	36	204

TABLE 2. OBSERVED AND PREDICTED MAXIMUM SURFACE CURRENTS. ALL TIMES ARE PACIFIC DAYLIGHT TIME AND ALL RATES ARE IN CENTIMETERS PER SECOND

	Ebb (max)			*Flood (max)*			*Ebb (max)*		
Station	*Rate*	*Time*	*Slack*	*Rate*	*Time*	*Slack*	*Rate*	*Time*	*Slack*
				Observed					
Buoy 21	78	0800	1100	56	1500	1630	65	2100	2315
Buoy 29	50	0845	1058	30	1400	1715	35	2100	2330
Buoy 45	32	0815	1107	24	1330	1745	34	2030	2330
				Predicted					
Bridge	145	0719	1009	121	1324	1623	130	1951	2236
Yaquina	73	0729	1019	73	1334	1633	65	2001	2246
1 mi. below Toledo	97	0804	1104	97	1409	1718	87	2036	2331

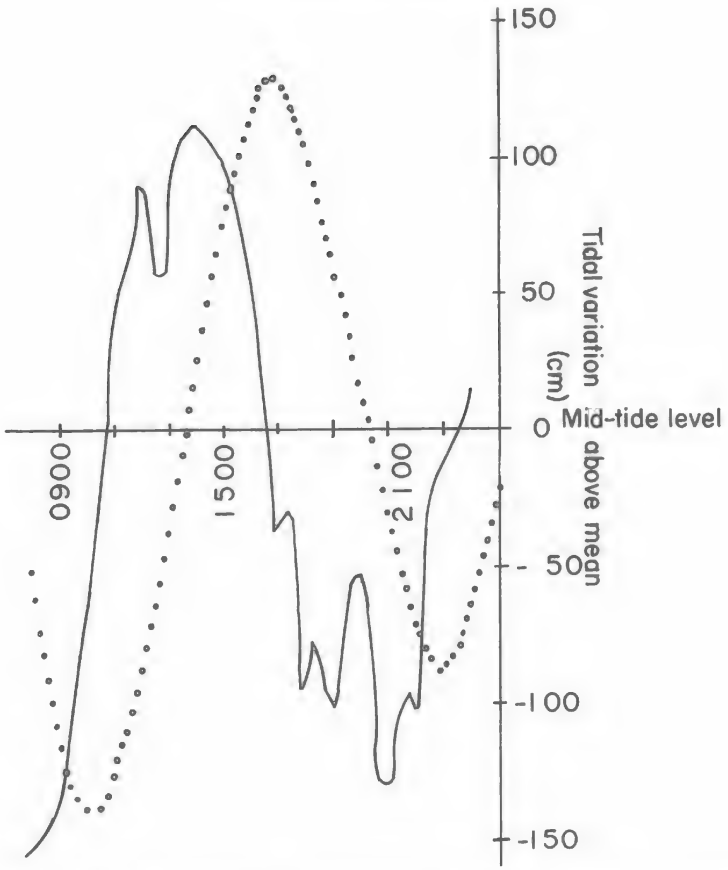

Figure 3. Phase relationship of the tide and currents at buoy 21. The dotted line represents the tide level (cm), while the solid line represents the surface current. The time in hours is shown on the horizontal axis. The greatest ebb current shown is –78 cm/sec, while the maximum flood current shown is +56 cm/sec.

while η_o is the maximum displacement amplitude and k is the wave number. The angular frequency is represented by ω. If this wave is reflected in such a way that a standing wave results, the equation for the standing wave displacement, η_s, is

$$\eta_s = 2\eta_o \cos kx \sin \omega t.$$

The point of reflection must occur at an antinode. To satisfy this requirement, x is taken as zero at the head of the bay. Therefore the tidal range must be a maximum at the head of the bay, decreasing toward the mouth.

An expression for the current, u, associated with a standing wave in

shallow water is

$$u = \eta \frac{c}{h} \sin kx \sin \omega t$$

where c is the wave celerity and h is the average depth of the water. The current predicted by this formula would be uniform in phase from surface to bottom. This equation predicts zero current where the tidal range is a maximum, i.e., at the point of reflection. The current, being out of phase with the tide, would therefore increase toward the mouth while the tidal range would decrease.

The wave length of a standing wave is one half that of the progressive wave. Therefore in order to have the tidal range decrease all the way from the head to the mouth of the bay, the bay must have a length not more than one fourth of the progressive wave length.

The tide and tidal currents in Yaquina Bay come remarkably close to fulfilling the requirements of a standing wave. The tidal range does increase upstream. The currents are in phase from surface to bottom. A stationary wave should have the strength of current coming nearly at midtide with slack water at or very near high and low tide. This requirement is approximately satisfied in Yaquina Bay. Standing waves would show high tide everywhere in the bay at the same time. However, according to Marmer (1932), some progressive wave movement is always present in tides. This is borne out in the case of Yaquina Bay where high tide does not come at exactly the same time everywhere. The length of tidal intrusion into Yaquina Bay must be less than one fourth the wave length of a progressive tide wave since no nodal point is reached inside the bay. This is not in agreement with Caldwell (1955), who gives the ratio of the estuary length to tide wave length in the estuary as 0.33.

Summary

The tide in Yaquina Bay closely satisfies the conditions predicted by the standing wave equation for shallow water. Some of the discrepancies in time at various stations may have been due to local wind conditions. Marmer (1932) indicates that the greatest irregularities in the tides in shallow waters may be caused by the wind. The wind can affect the height as well as the time of tide.

The present tide and current predictions available for Yaquina Bay show some errors that should be recognized by those planning work in the bay. The tidal ranges were underestimated at all stations, while errors in time

were generally small (30 minutes or less). However, these errors were generally premature and hence could not have been accounted for by the local wind effect.

As was mentioned above, the current predictions did not show the correct difference between strength of flood and strength of ebb. The ebb was actually observed to be greater.

With the increased use planned for this bay in the near future, it seems that the tidal predictions need to be revised.

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Muscular Degeneration Produced by Experimental Transport Stress in Pigs

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MUSCULAR DEGENERATION is a pathological finding widespread in pigs. The most numerous reports on muscle degeneration are connected with a disease called transport muscle dystrophy, which occurs after transport or after transport and slaughter. Animals that seem healthy on the farm may die suddenly during transport or shortly thereafter. In other cases change may be observed in the meat of slaughtered animals. Postmortal changes in the muscle include pallor, edema, hemorrhage, and softening. The cut surface of affected muscle displays a marked moistness. The microscopic picture is characterized by fragmentation of muscle fibers, dissolution of myofibrils and sarcoplasm, disappearance of striation, separation of endomysium, and massive edema. The changes in the muscle are considered to be the result of muscle glycogen breaking down to lactic acid, which in turn lowers pH below 6.2. This acid condition is believed to bring about denaturing of protein. An associated lowered electrical resistance may be a more important factor.

The purpose of this experiment is to ascertain if muscle degeneration can be regularly produced in healthy pigs of slaughter weight (180-225 pounds) under laboratory conditions and to determine the associated clinical manifestations.

Materials and Methods

The experimental pigs belong to the Swedish Landrace or a mixture of this race with the English Large White Breed. The animals fall within the 180-225 pound weight range. Both females and castrated males are represented. Prior to the experiment the animals were examined. Their health was controlled by the veterinary surgeons of the staff of the Royal Veterinary College, Stockholm, and the animals were found to be free of disease. Before and during experimentation they were kept in separate group quarters.

Methods

The animals were placed within a special transport-simulating pen that was mounted on a horizontal, roughened rail course. The pen was coupled

to a piston of two-foot stroke driven by an electrical motor. Transport stress was induced by subjecting the animals to a reciprocating motion brought about by driving the piston. However, travel was assisted by a plurality of rollers fixed to the running surface of the pen. The duration of shaking in this pen was four hours, during which time the outside temperature of the room was maintained between 93-100°F (34-38°C). The rate of drive of this device loaded was 30 cycles/minute.

Blood for preparation of plasma was drawn in heparin from the anterior vena cava. Glutamic oxaloacetic transaminase (GOT) and ornithine carbamyl transferase (OCT) values were determined from plasma immediately after centrifuging or within 24 hours with centrifuged blood which had been stored in a refrigerator.

GOT values were arrived at spectrophotometrically by the method of Reitman and Frankel (1957). Normal blood GOT and OCT levels are accepted from the work of Wretlund and Orstaduis (1959). Mean values and standard deviations for GOT are 28.03 $\pm$ 15.39 and for OCT are 5.93 $\pm$ 2.42.

GOT shows increased blood-serum levels in various diseases involving tissue necrosis in man and animals. It has been demonstrated in muscular disorders, heart infarct, liver damage, and necrosis of other organs. Experiments with dogs and pigs show liver to have high levels of OCT, whereas other organs have a low concentration. Muscle dystrophy is associated with increased plasma levels of GOT, whereas liver dystrophy causes rise of OCT as well. The study of these enzymes provides a reliable method of following conditions of muscle in living pigs and shows that changes in the liver are not responsible.

Biopsy specimens of skeletal muscle were taken from the longissimus dorsi under trichloroethylene narcosis. The specimens were 2 x 1 x 0.5 cm. in size. They were fixed in formalin after standing in moist air for four hours. This period was to allow time for postmortal glycogen changes, as previously described. Specimens were then mounted, stained with hematoxylin eosin, and paraffin embedded.

Procedure and Results

Before the experiment the pigs were left undisturbed for a minimum of a week in their isolated pens. Three series of clinical tests and biopsies were then taken with the same pigs, 23 in number, as described in Materials. The first series was for control findings. This series was further facilitated by an intramuscular injection of 2 mg. of phylegacil/pound of body weight to

calm the animals. All the plasma enzyme findings obtained fell within the normal range. Biopsies of longissimus dorsi taken under trichloroethylene narcosis appeared microscopically to be healthy reddish muscle with a firm consistency. The histological picture was that of normal muscle.

After 24 hours' rest the animals were shaken for four hours in the electrically driven and heated transport-simulating pen as described in Methods. Upon removal from the machine all animals appeared apathetic. They preferred to lie and showed locomotive disturbances. When forced to rise, they stood with arched backs. When forced to move, atony was observed. They also displayed tachycardia and tachydyspnea. All of the GOT values

TABLE 1

	"GOT"			*"OCT"*			*Micro-*	*Micro-*	*Degree of Muscle Degeneration and Remarks*
No.	*PP*	*S*	*SS*	*P*	*S*	*SS*	*scopic*	*scopic*	
65	39	69					*	+++	
66	47.5	100.5					*	++++	
68	37	57					*	++	
69	35.5	119.5					*	++++	
70	34	74					*	+++	
72	41.5	149.5					*	++++	
76	49.5	75					*	+++	
77	45	58.5					*	+++	
2001	----	74					*	+++	
2002	----	72					*	+++	
2036	14	67			1.5		*	+++	
2004	18	64			4.5		*	+++	
2008	35	48		3	1.5		*	tech. fault with slide	
2028	15	103		0.5	2.0		*	tech. fault with slide	
3006	14	74					*	tech. fault with slide	
5079	14	60	28	10.9	3.3	1.7	*		
5076	16	87	34.5	2.2	0	2.2	*		
5004	16	87	31	6.9	5.5	2.7	*		
5022	16	51	31	0.5	2.2	2.2	*		
6018	15.5	26.5	14.5	1.1	4.4	3.3			
6006	25	25	19	1.7	4.4	3.8			
6004	21.5	23	18.5	2.2	3.3	0.5			
6026	19	33	25	2.2	2.2	0			

* Appeared microscopically after 4 hours in moist air noticeably softer in consistency, gray-white in color and moist on the cut surface.
\+ Minimum histological muscle degeneration.
++ More than minimal muscle degeneration.
+++ Muscle degeneration histologically observed.
++++ Marked muscle degeneration histologically observed.
P Control findings.
S Stress findings.
SS Findings 24 hours after stress.

except one were elevated by the experiment. Sixty per cent of these passed into the pathological category. The OCT values showed no significant change and in all cases remained within the normal limits. This indicates that the changes that occurred in the stressed animals were in their skeletal muscle masses and not in their livers. Microscopic inspection of the biopsies after standing in moist air for four hours showed them to be noticeably softer in consistency and more gray-white in color than normal muscle similarly exposed. They had a markedly moister cut surface following biopsy. All microscopic slides, fixed as described in Methods, showed muscle degeneration to some extent. Good agreement was found between the histological examination and the plasma GOT findings. When one was normal the other was also, as in the control tests. When the GOT findings were pathologically elevated, the histological findings were correspondingly more marked in their degeneration.

Twenty-four hours after stress, blood was drawn again from eight animals. The GOT and OCT findings in the tests fell within the normal range and relatively close to the control findings.

Conclusions

Some muscle degeneration can be regularly produced in healthy pigs of slaughter weight by four hours of simulated transport shaking at 34°C.

The clinical manifestations are:

1. Plasma GOT findings elevated compared with those taken prior to transport stress.

2. Plasma OCT levels remain within normal range indicating seat of tissue destruction to be in the skeletal muscle masses and not in the liver.

3. After allowing all biopsy specimens to stand in moist air for four hours, histological examination shows definite muscle degeneration after transport stress as compared with control biopsies taken prior to the stressing.

4. A direct relationship exists between extent of muscle degeneration and rise in plasma GOT.

5. Plasma GOT levels return to within normal limits after a 24-hour recovery period in living pigs.

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A Painted Turtle (Chrysemys picta) with Ulcers in the Stomach and Duodenum

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ULCERS OF the gastrointestinal tract have not been previously reported from any species of cold-blooded vertebrate, although the gross and microscopic morphology of ulcers as pathological lesions in humans is well known.

Ulcerative stomatitis, commonly called "mouth rot," has been described from several species of snakes held in captivity (Burtscher, 1932; Book, 1945; Klauber, 1956; Page, 1961, 1962). This disease manifests itself as ulcerative lesions in or around the oral cavity, and is apparently due to an aeromonad bacterium (Page, 1961). Bacteria have also been isolated from the ulcerated skin lesions of fish, frogs, lizards, and toads (Fish, 1934; Wolf, 1939, 1941; Reed and Toner, 1941, 1942; Wagner and Perkins, 1952; Davis, 1956; Page, 1961, 1962; Snieszko and Bullock, 1962; Meyer, 1964; and others) and from ulcerations of the oral cavities of fish (Wolf, 1939, 1941; Davis, 1956: 256).

During the examination of a painted turtle (*Chrysemys picta*) for gastrointestinal parasites, two ulcers (6 mm and 7 mm in diameter) were observed in the pyloric portion of the stomach and one smaller ulcer (2 mm in diameter) was observed in the duodenum. The gross appearance of the smaller ulcer was similar to lesions of this type found in humans (Robbins, 1962: 79-80). There was no discoloration of the ulcer or the surrounding area. The two larger ulcers in the stomach were black, had a smooth, glassy appearance, and, since they did not have an excavated appearance, were not recognizable as ulcers upon gross examination.

The ulcerated areas, with a surrounding portion of normal tissue, were removed and placed in Bouins fixative, along with the liver, lungs, and spleen. These tissues and organs were dehydrated by standard methods, embedded

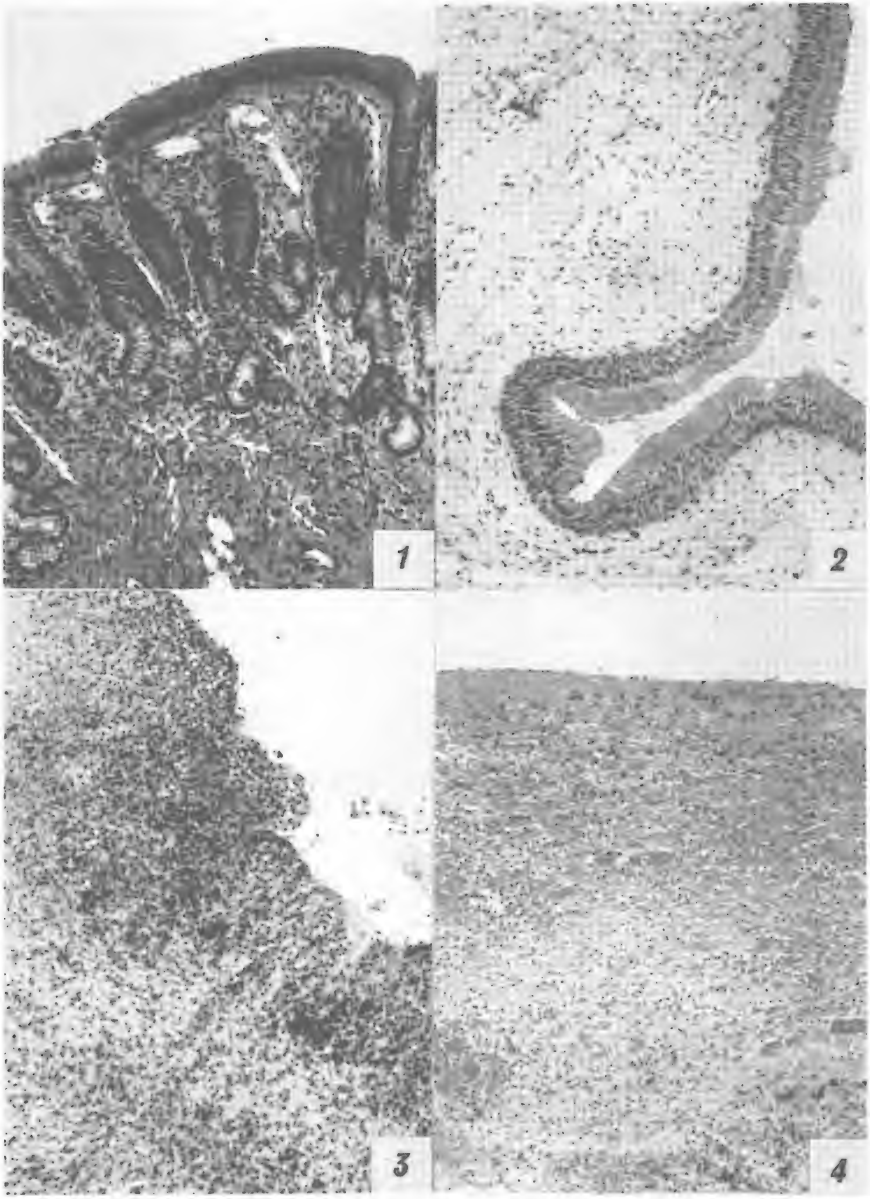

Figure 1. Normal intestinal epithelium 205 X. Figure 2. Normal stomach epithelium 205 X. Figure 3. Intestinal ulcer. Note heavy infiltration of eosinophilic leucocytes (black dots), especially near the surface 205 X. Figure 4. Stomach ulcer. Note smooth surface of compacted collagen 205 X.

in Paraplast, sectioned at 7 microns, and stained with Erlich's hematoxylin and eosin, Masson's trichrome, and Mallory's triple stain.

The two stomach ulcerations had the same histological appearance (Figure 4), with both penetrating into the *tunica muscularis.* They were laminated and had a smooth surface composed of compacted collagen that was hyaline in appearance. Under the collagen was a highly vascularized layer of fibrous tissue containing many eosinophilic leucocytes. This was underlaid by a layer of necrotic neutrophilic leucocytes with pycnotic nuclei. Another very thick layer of eosinophils formed the base of the ulcers. The entire ulcerated area and the surrounding normal tissue were heavily infiltrated with eosinophils. These lesions were heavily infiltrated by collagen and fibrous tissue and were highly vascularized, indicating an advanced stage of wound repair. Since they lacked an excavated appearance, these lesions were thought to be chronic ulcerations. However, there was no suggestion of epithelial regeneration over the ulcerated stomach areas.

The histological appearance of the duodenal ulcer was quite different from those found in the stomach. It had almost completely penetrated the *tunica submucosa,* but had not eroded into the *tunica muscularis.* The upper part of the lesion was an open pit lined by a thick layer of eosinophilic leucocytes (Figure 3). This ulcer also lacked any sign of epithelial regeneration. The lower portion of it was highly vascularized and infiltrated by collagen and fibrous tissue, indicating that wound repair was proceeding. This ulceration showed signs of acute inflammation with large numbers of neutrophilic leucocytes present in the tissue adjacent to it. There were also many eosinophilic leucocytes present in this lesion and the surrounding tissue. However, there were not as many eosinophils present in the intestinal ulcer as were present in the stomach ulcerations. Fish (1934), in his microscopic discussion of the external ulcers found on trout, noted that the infected area was infiltrated by polymorphonuclear leucocytes and that a mononuclear infiltrate was present within healing tissue. However, these lesions in the turtle apparently lacked the monocytes present in the fish ulcerations.

All three of these ulcers exhibited a marked fibroblastic proliferation, scarring, heavy vascularization, and the accumulation of numerous eosinophils and neutrophils. The cause of these ulcerations is unknown, but it is possible that they may be due to a bacterium, since aeromonad bacteria are usually recovered in association with diseased tissues of cold-blooded vertebrates (Page, 1961).

It was noted that the spleen contained an abnormal increase in the number of eosinophilic leucocytes. The liver and the lungs were normal.

Acknowledgements

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NORTHWEST SCIENCE

Volume 40, No. 3, August 1966

CONTENTS

The Genus Phausis in America North of Mexico (Coleoptera-Lampyridae). *Kenneth M. Fender* 83

Significance of the Scarcity of Early Pleistocene Glacial Deposits in the Western United States. *Eugene H. Walker* 96

Artificial Ripening of Grand Fir Cones. *Robert D. Pfister* 103

Vegetation Following Slash Fires in One Western Oregon Locality. *Harold K. Steen* 113

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THE NORTHWEST SCIENTIFIC ASSOCIATION is an association representative of the basic and applied sciences and of social science. The purpose of the Association in the annual meetings and in the publication, *Northwest Science*, is to integrate and report upon the significant work being done in the Pacific Northwest in these fields.

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The Genus Phausis in America North of Mexico (Coleoptera-Lampyridae)[1]

KENNETH M. FENDER
Linfield Research Institute
McMinnville, Oregon

THE SPECIES of the genus *Phausis* have been neglected in North America because of their small size, lack of economic importance, and scarcity in collections. They are rather dull in color and thus seemingly have not invited enthusiastic study.

The European species *Phausis splendidula* Linnaeus has been recorded from North America. Large specimens of *Phausis reticulata* Say have been examined that were labeled "*Phausis splendidula*" but were definitely misnamed. The writer is inclined to believe that *P. splendidula* does not occur on our continent; however, lest he be in error, a description and drawings of that species are included.

PHAUSIS LeConte

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Lamprohiza Motschulsky. 1852, Etudes Ent., P. 47.
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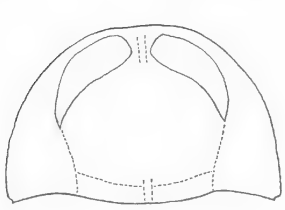
Phausis Green. 1948, Trans. Am. Ent. Soc., 74:69.
Phausis Fender. 1961, Univ. Wash. Pub. Biol., 16(3):42-43.

This genus may be distinguished from other North American genera by the 11-segment antennae, the ultimate segment with a minute apical appendage; the abdominal spiracles dorsal; pronotum with or without two anterior translucent to transparent spots; mandibles well developed, arcuate and decussate with the tips acute.

[1] Supported by National Science Foundation grant No. NSF GB-4097.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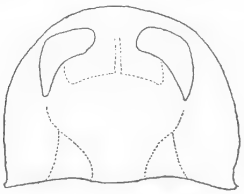
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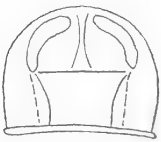
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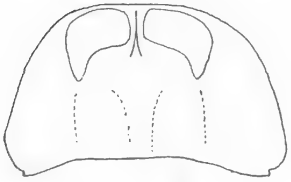
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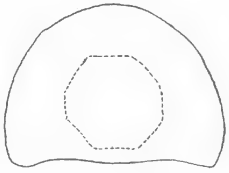
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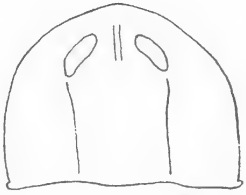
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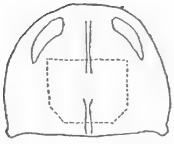
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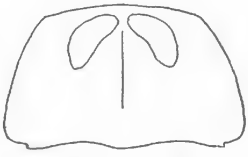
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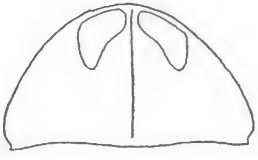
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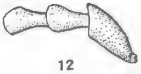
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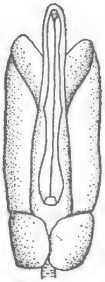
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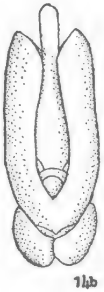
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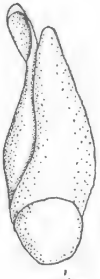
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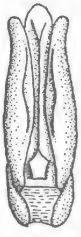
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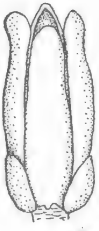
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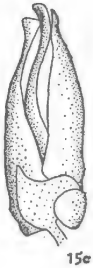
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Phausis splendidula Linnaeus

(Plate I, figs. 1, 12, 14A, 14B, 14C)

Lampyris splendidula Linnaeus. 1767, Syst. Nat., 1:644. *Lampyris splendidula* Olivier. 1790, Entomologie, 2(28):11. *Lamprohiza splendidula* Duval. 1859, Glan. Ent., 1:20. *Lamprorhiza splendidula* Mulsant. 1862, Hist. Nat. d. Col. de France, 12:113. *Phausis splendidula* LeConte. 1881, Trans. Am. Ent. Soc., 9:36. *Lamprohiza splendidula* Blatchley. 1910, Bull. Ind. Dept. Geol. & Nat. Res., 1:823. *Phausis splendidula* Hopping. 1937, Can. Ent., 69:90.

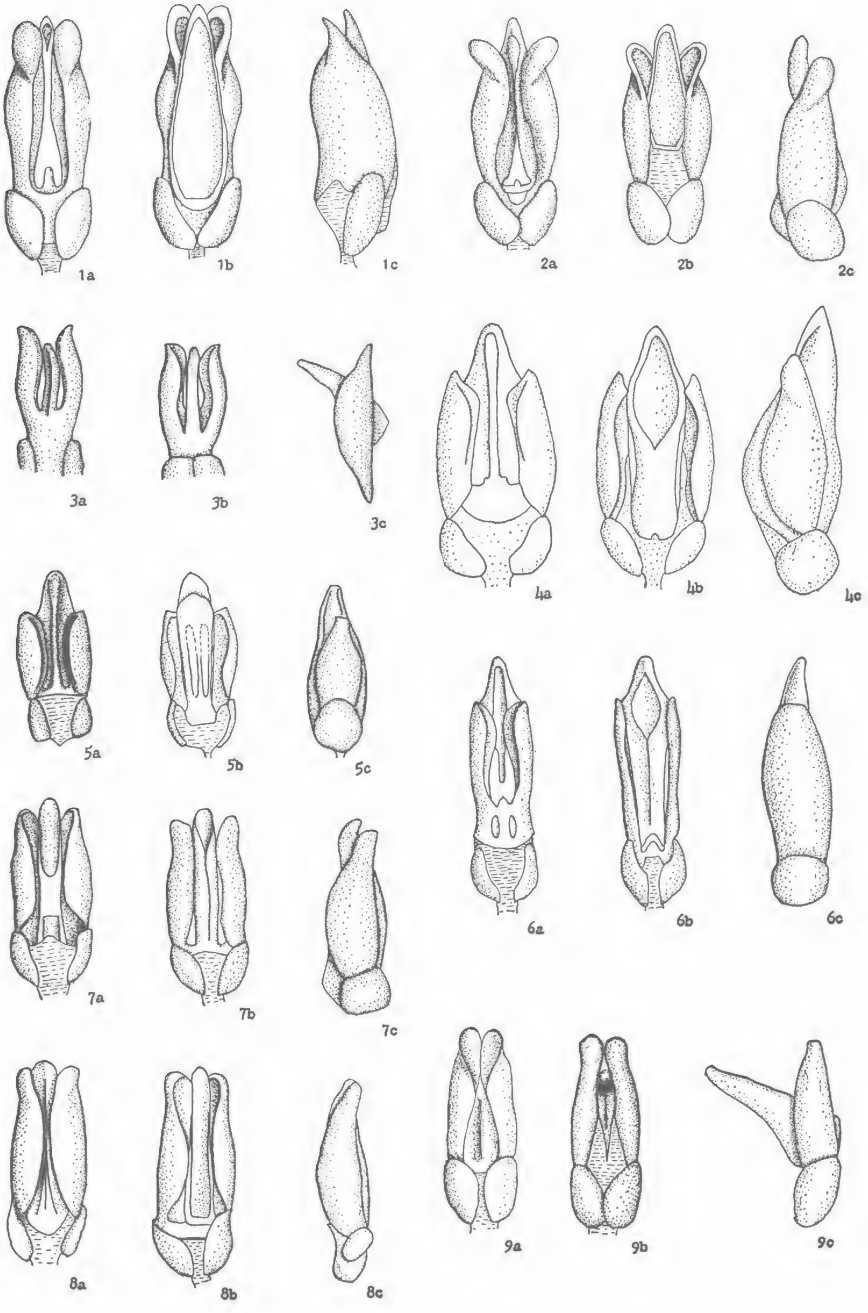
Piceous to brunneous. Head nigropiceous, eyes black. Pronotum with a median subquadrate nigropiceous spot, anterior to this and on each side of the middle, a large curved oblanceolate transparent spot. Elytra feebly darker inwardly and toward the base. Sternites 5 and 6 each with a large transversely obovate yellowish white luminiferous spot. Length 8 to 8.5 mm.

Male. Head longitudinally concave and finely sparsely punctured above and between the eyes, eyes large and prominent, obviously separated beneath; antennae slender, short, terete, segments two and three both elongate and of equal length. Pronotum shining, transverse, subelliptical, widest near the base, the sides straighter and more strongly converging before evenly curving into the anterior margin, the anterior angles obsolete, all margins reflexed, the hind angles denticulate, the basal margin bisinuate; anterior transparent spots impunctate, sides and the anterior area between the transparent spots falcate, closely, coarsely, confusedly punctured, the punctures usually circular, sometimes irregular, variable in size, some punctures contiguous or connate, basal half of the disc finely sparsely punctured, basal gutter coarsely closely so; a feeble elevated longitudinal median ridge, extending from the middle to the apical margin. Scutellum shining, short, subtriangular, the sides arcuate, finely punctured. Elytra four times as long as the pronotum, obovate, the lateral margins widely explanate; coarsely, closely subreticulate-punctate basally, becoming more finely rugose punctate at and beyond the middle, rather feebly costate. Body beneath shining, the abdomen duller, the sides of the abdominal segments five and six strongly produced caudally and acute; sides of the seventh tergite less strongly so; seventh sternite slender, elongate, apically notched.

Female. Unseen.

This description is based on specimens collected at Laningen, nr. Danube, Bavaria.

Plate I. Figures 1-11, Pronota of males of *Phausis*. 1. *Ph. splendidula* Linnaeus. 2. *Ph. reticulata* Say. 3. *Ph. luminosa* Fender. 4. *Ph. inaccensa* LeConte. 5. *Ph. dorothae* Fender. 6. *Ph. californica* Fender. 7. *Ph. riversi* LeConte. 8. *Ph. marina* Fender. 9. *Ph. rhombica* Fender. 10. *Ph. nigra* Hopping. 11. *Ph. skelleyi* Fender. Figures 12-13, Basal antennal segments of *Phausis*. 12. *Ph. splendidula*. 13. *Ph. luminosa* Fender. Figures 14-15, Aedeagae of males of *Phausis*. (A=dorsal aspect; B=ventral aspect; C=lateral aspect). 14. *Ph. splendidula* Linnaeus. 15. *Ph. reticulata* Say.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Phausis reticulata Say
(Plate I, figs. 2, 15A, 15B, 15C)

Lampyris reticulata Say. 1825, Journ. Ac. Nat. Sci. Phila., 5:163. *Phausis reticulata* LeConte. 1881, Trans. Am. Ent. Soc., 9:36. *Phausis reticulata* Hopping. 1937, Can. Ent., 69:90.

Brunneous. Eyes black, median portion of the pronotal disc blackish brown; anterior hyaline spots present. Elytra with brassy reflections on basal half. Margins of the scutellum and elytral suture at the scutellum paler. Thorax beneath paler toward the sides, sternites five and six each with a large transverse median luminiferous yellowish white area. Coxae, trochanters, tarsi and basal half of the femora paler. Pubescence brunneus. Length 5 to 8.5 mm.

Male. Head longitudinally concave and finely sparsely punctured dorsally; eyes large and prominent, more widely separated beneath, not encroaching on the ventral mouth parts; antennae feebly compressed, short, second segment short and transverse, one-third or less the length of the third. Pronotum transversely subelliptical, two-thirds as long as wide, widest near the basal fourth, sides more arcuate and less strongly convergent before the evenly rounded anterior margin (than *P. splendidula*), all margins reflexed, very strongly so anteriorly on the side margins and frontal margin, becoming flattened toward the hind angles, the hind angles denticulate, the basal margin bisinuate, the anterior hyaline areas irregularly sub-reniform, impunctate, the reflexed margins and anterior median portion (between the hyaline spots) confusedly reticulate, basal median region shining and finely sparsely punctured; reticulate areas composed of closely spaced punctures of varying size, some large deep punctures enclosing one or more small punctures, giving a three-dimensional effect to the reticulations. Scutellum dull, digitate, the sides sinuate, the surface finely punctured. Elytra coarsely closely punctate to reticulate punctate basally, becoming more finely reticulate apically, a single evident discal costa on each and with faint indications of a sub-sutural costa. Body beneath with metathorax shining and finely sparsely punctured; abdomen dull, finely sparsely punctured; sternites five and six with large luminiferous areas extending nearly to the margins of the segments.

Female. Unknown.

LeConte cited this species from Georgia, Tennessee, and Texas. Examples have been examined from Cranberry, Cherokee, and Black Mts., North Carolina and Deer Lodge and Elmwood, Tennessee. It appears to be our commonest species and centered in the Black Mts. of North Carolina from where a large number of specimens have been seen.

Plate II. Figures 1-9, Aedeagae of males of *Phausis*. (A=dorsal aspect; B=ventral aspect; C=lateral aspect). 1. *Ph. luminosa* Fender. 2. *Ph. inaccensa* LeConte. 3. *Ph. dorothae* Fender. 4. *Ph. californica* Fender. 5. *Ph. riversi* LeConte. 6. *Ph. marina* Fender. 7. *Ph. rhombica* Fender. 8. *Ph. nigra* Hopping. 9. *Ph. skelleyi* Fender.

Phausis luminosa Fender, new species

(Plate I, figs. 3, 13. Plate II, figs. 1A, 1B, 1C)

Brunneous to yellowish brown. Eyes black. Median pronotal spot darker than the margins. Scutellum testaceous. Elytra with or without the lateral margins obscurely paler, the apices feebly dusky. Legs brunneous with the femora paler. Basal four abdominal segments brownish, the basal lateral angles widely testaceous to brownish testaceous, segments five and six entirely testaceous, the luminiferous areas smooth and slightly elevated. Pubescence brownish. Length 5 to 5.5 mm.

Male. Head transverse, longitudinally concave between and behind the eyes dorsally; eyes large and prominent, separated by at least half their individual width; antennae short, terete, second segment half the length of the third, third segment obviously longer than succeeding segments, segments four to eleven subequal. Pronotum subelliptical, six-sevenths as long as wide, the basal margin nearly straight, the basal angles not denticulate, all margins widely rather shallowly reflexed, more deeply so anteriorly and toward the sides; translucent anterior spots present, large and finely sparsely punctured; marginal reflexed and anterior half of the pronotal disc reticulate-punctate, the basal half of the disc shining and finely sparsely punctured. Scutellum spatulate, apically rounded, a median longitudinal groove extending nearly to the apex. Elytra strongly reticulate. A rather strong discal costa and on either side, a weak but evident costa. Body beneath shining, finely sparsely punctured, more coarsely so on the abdomen; luminiferous areas of segments five and six impunctate. Apical angles of segments five and six strongly produced and acute caudally, apical angles seventh tergite less strongly and sharply produced; seventh sternite elongate-spatulate. Protibiae and mesotibiae less strongly bent toward the base than in allied species.

Female. Unknown.

Holotype. Male, Oklahoma City, Oklahoma. No date, collected by Chapman Grant. Two male paratypes, Lawrence Co., Arkansas, collected by B. C. Marshall.

Phausis inaccensa LeConte

(Plate I, fig. 4. Plate II, figs. 2A, 2B, 2C)

Phausis inaccensa LeConte. 1878, Proc. Am. Philos. Soc., 17:611. *Phausis inaccensa* LeConte. 1881, Trans. Am. Ent. Soc., 9:36. *Lamprohiza inaccensa* Blatchley. 1910, Bull. Ind. Dept. Geol. & Nat. Res., 1:823. *Phausis inaccensa* Hopping. 1937, Can. Ent., 69:90.

Yellowish brown. Head and median pronotal spot piceous. Elytra olivaceous the lateral margins obscurely paler. Abdomen dark brown, fifth sternite with the apical margin narrowly pale. Sixth sternite with the sides and apical margin widely pale; laterally produced tergites yellowish brown; legs yellowish brown with the tibiae and tarsi somewhat darker. Pubescence grayish. Length 5 to 6.5 mm.

Male. Head longitudinally concave and finely sparsely punctured between the eyes above; eyes large and prominent, approximate beneath; antennae feebly compressed, the second segment one-third the length of the third, segments three through six subequal in length, seven to ten progressively shorter, eleventh longer and ovate. Pronotum transverse, about three-fifths as long as wide, widest at basal fifth, the anterior margin feebly bisinuate, nearly straight, evenly curving into the broadly

arcuate and diverging sides, the hind angles finely denticulate, the basal margin broadly concave; all margins reflexed, broadly so at anterior margin and sides, the sides becoming explanate toward the hind angles; disc finely sparsely punctured on the basal half, median portion of apical half finely rugose punctate; anterior transparent spots triangular, finely punctured, a median longitudinal ridge extending from the middle to the apical margin, narrowly separating the transparent spots. Scutellum short, spatulate, with a median longitudinal groove. Elytra rugose punctate basally; reticulate medially and to the apices, costae obliterated, the outer basal angles sinuate, the laterial margins widely explanate, the reticulations thereon finer. Thorax beneath feebly shining, finely sparsely punctured; the abdomen dull, finely sparsely punctured and finely strigulose transversely, luminiferous areas absent. Legs normal for the genus, the metatibiae noticeably sinuate. Pubescence fine, sparse and recurved.

Female. Unknown.

Specimens of this species have been examined from Tannersville, Pennsylvania.

Phausis dorothae Fender

(Plate I, fig. 5. Plate II, figs. 3A, 3B, 3C)

Phausis dorothae Fender. 1961, Univ. Wash. Pub. Biol., 16(3):42.

Castaneous. Eyes a little darker, antennae brunneous above, pale brunneous beneath; palpi, legs and last four sternites brownish yellow. Pronotum brownish yellow with a rectangular discal dark spot. Elytra with the lateral margins obscurely paler basally. Sides of the basal abdominal segments brownish yellow. Pubescence cinereous to aureous. Length 5.5 to 6 mm.

Male. Head finely closely punctate, shallowly longitudinally concave behind the eyes dorsally; eyes small, moderately prominent; antennae short, stout and terete, the second segment short, transverse, segments three and four equal, the fourth through the tenth shorter, eleventh slightly longer and narrower than the tenth, the appendix short, transverse. Pronotum subelliptical, two to two and a half times as wide as long, margins strongly reflexed toward the obliterated anterior angles, less strongly so on the anterior and posterior margins, becoming explanate toward the hind angles, anterior transparent areas absent; disc shining and finely punctured in the pronotal dark spot, the remainder dull and finely closely reticulate. Scutellum longer than wide, apically truncate, finely rugose punctate. Elytra apically subulate, confusedly reticulate, costae absent. Body beneath shining, metasternum finely sparsely punctured, metasternal episternum more coarsely so; abdominal sternites finely, sparsely pustulate-punctate; luminiferous organs absent. Pubescence fine, sparse and depressed.

Female. Unknown.

The type of this species is from Reuben Creek, Oregon. Additional specimens have been studied from the following California localities: Upland, Mill Valley (Marin Co.), Castle Crags.

Phausis californica Fender, new species

(Plate I, fig. 6. Plate II, figs. 4A, 4B, 4C)

Piceous. Prothorax, front of head, pronotum, seventh sternite and sides and apical margins of the fifth and sixth sternites flavous. Scutellum, antennae, and legs brunneous,

prolegs and bases of the antennae paler, explanate lateral margins of the elytra narrowly brunneous. Pubescence cupreous. Length 4.5 to 6 mm.

Male. Head short, transverse; eyes small and remote; antennae compressed, the second segment one-third the length of the third, segments four through eleven subequal, each shorter than the third, the appendix of the eleventh short and truncate. Pronotum subelliptical, one-fifth wider than long, the anterior and lateral margins strongly reflexed, become more explanate toward the hind angles, the hind angles dentate, the posterior margin bisinuate, narrowly, moderately deeply guttered; the anterior translucid spots small, falcate, finely sparsely punctured; reflexed margins reticulate punctate; disc convex, shining, coarsely sparsely punctured, a low median carina extending from the basal fourth to the apical sixth, feebly elevated medially. Scutellum shining, feebly broadened apically, the tip truncately rounded, coarsely sparsely punctured. Elytra four times the length of the pronotum, finely rugose apically, basally becoming confusedly punctate, with intermingling large and small punctures; subsutural and discal costae feebly indicated, shining, faintly elevated and eroded. Meso- and metathorax shining, finely sparsely punctured; abdominal sternites finely pustulate and with fine transverse rugae; the apical tergite strongly lobed at the sides, the penultimate tergite with a large triangular apical notch. Pubescence fine and sparse.

Female. Unknown.

Holotype. Male. Lake County, California. Two paratypes. Tuolomne Co., California.

Phausis riversi LeConte

(Plate I, fig. 7. Plate II, figs. 5A, 5B, 5C)

Phausis riversi LeConte. 1885, Trans. Am. Ent. Soc., 12:20. *Phausis riversi* Hopping. 1937, Can. Ent., 69:90. *Phausis riversi* Fender. 1961, Univ. Wash. Pub. Biol., 16(3):42.

Brownish black, basal antennal segments paler, clypeal apex and mandibles flavous. Pronotum flavous with a large median sub basal black spot, transparent spots present. Abdominal sternites five and six with the sides and apices more or less widely flavous, usually more widely so on the sixth, nonluminous. Legs brunneous, the prolegs with the apices of the coxae, trochanters and bases and apices of the femora widely but obscurely paler, less widely so on the middle legs, very narrowly obscurely so on the hind legs. Pubescence aureous to cupreous. Length 4 to 6 mm.

Male. Head transversely concave and rather coarsely closely punctured behind the antennae, longitudinally rugose between the antennae, shining and impunctate in front; eyes moderately small, remote; antennae moderately stout, extending to about the middle of the metathorax, moderately compressed basally, more strongly so apically, segment two short and transverse, about one-third the length of the third, segments three to ten progressively narrower and shorter, the eleventh ovate, the appendix minute, white. Pronotum about five-sixths as long as wide, semicircular, the anterior and lateral margins evenly arcuate, the anterior angles obsolete, the basal angles bluntly denticulate, the lateral margins widely deeply reflexed, a little more deeply so anteriorly, the anterior margin widely less deeply so, the basal margin bisinuate and rather thickly beaded; the anterior transparent spots small and remote, falcate; reflexed margins finely closely rugose punctate, the median area convex, shining and finely sparsely

punctured. Scutellum with sides sinuate, expanded toward the apex, apically subtruncately rounded, coarsely sparsely punctured, with a median longitudinal groove. Elytra slender, nearly five times the length of the pronotum, the lateral margins feebly sinuate, rather widely explanate; basally closely punctured with intermixed fine and coarse punctures, more sparsely so on the humeral umbones, becoming rugose punctate medially and a little more coarsely so apically. Metasternum shining, finely sparsely granulate-punctate, the abdominal sternites a little duller and a little more closely granulate-punctate, especially so toward the sides. Pubescence recumbent, fine, sparse and inconspicuous.

Female. Unknown.

Specimens have been examined from the following localities: California: Carrville (Trinity Co.), Pyrimid Ranger Station (Eldorado Co.), Castle Crags, Burney Falls (Shasta Co.), Mill Valley, Marin Co. Oregon: Pistol River.

Podabrus marina Fender, new species

(Plate I, fig. 8. Plate II, figs. 6A, 6B, 6C)

Dark brown to olive brown. Clypeal apex and the apical half of the mandibles flavotestaceous, in pale specimens, the apex of the last maxillary segment testaceous. Pronotum with the pronotal bead paler varying to the reflexed lateral apical margins paler; anterior spots transparent. Elytra blackish brown. Abdominal sternites five and six with the apical and lateral margins widely, more or less obviously paler. Apices of the coxae, trochanters, bases of the femora paler. Pubescence aureous to brownish on the dorsal surface, piceous ventrally and on the appendages. Length 3 to 5 mm.

Male. Head very shallowly transversely concave between the eyes, the occiput granulose toward each side; the eyes small and remote; the antennae compressed, extending to about the midde of the metasternum, the second segment short and transverse, one-third the length of the third; the third through the tenth subequal, the eleventh slightly longer, the apex truncately rounded; the appendix small, at times difficult to distinguish. Pronotum semicircular, five-sixths as wide as long, widest at about the basal eighth, lateral and apical margins evenly arcuately rounding into each other, the anterior angles obsolete, basal margin feebly bisinuate, the basal angles rather strongly, prominently dentate; anterior translucent spots impunctate, small and remote, unevenly ovate in outline, pronotal margins rather widely shallowly reflexed, a little more so toward the anterior angles, the sides becoming explanate toward the hind angles, the lateral margins and anterior half reticulate punctate, basal half of median convex area shining, finely sparsely punctured, a median longitudinal elevation faintly indicated. Scutellum shining elongate, the sides concave, the apex shallowly notched, surface shining, with or without a shallow median longitudinal impressed line, finely sparsely punctured. Elytra slender and long, four and a quarter times the length of the pronotum, five and a half times as long as their individual widths; moderately coarsely confusedly punctate basally, more coarsely so medially, becoming scabrose apically, with a discal costa more or less feebly indicated. Body beneath shining and finely sparsely punctured, the metosternum smooth; abdominal sternites duller and finely sparsely pustulate, the sides of tergites four to six less widely produced, the apical angles less acutely produced, legs compressed, more slender than usual for the genus. Pubescence depressed, fine, sparse and inconspicuous.

Female. Unknown.

Holotype. Male, Mill Valley, Marin Co., Cal., June 7, 1949. Collected by Hugh B. Leach "in house." Seven paratypes, same locality collected from May 4 to July 7.

Phausis rhombica Fender

(Plate I, fig. 9. Plate II, figs. 7A, 7B, 7C)

Phausis rhombica Fender. 1961, Univ. Wash. Pub. Biol., 16(3):43.

Piceous to black. Mandibles testaceous, antennae brownish piceous. Reflexed pronotal margins paler, legs and abdomen brownish piceous, the trochanters and apices of the coxae piceo-testaceous. Pubescence brownish on the dorsal surface and elytra, aureous to cinereous on the ventral surface and appendages. Length 6 to 7 mm.

Male. Head dull, finely, rather closely punctured in front, transversely concave between the eyes; the eyes rather small, remote beneath; the antennae short, terete, the second segment transverse one third the length of the third, segments three through ten becoming succeedingly shorter and narrower, the eleventh segment longer than the tenth, ovate, the appendix very short, and truncate. Pronotum subrhombic, widest at about the basal sixth, seven-tenths as long as wide, the basal margin shallowly bisinuate the apical angles denticulate, the sides feebly arcuate, converging before near the hind angles to the equally feebly arcuate anterior margin, the anterior angles more sharply arcuate, rather obscurely indicated, sides and anterior margin broadly reflexed, more deeply so toward the anterior angles, the basal margin narrowly reflexed, the marginal bead of the base fine medially, thickening toward the sides, the reflexed sides rather coarsely reticulate-punctate; the anterior translucent spots large, subquadrate-falcate, finely punctured; the disc shining, finely sparsely punctured medially, becoming finely scabrous punctate toward the base. Scutellum subspatulate, the apex finely notched, finely sparsely punctured, a longitudinal median impressed groove extending from about the middle to the apex. Elytra basally rugose punctate, the punctures confused and of variable size, becoming finely reticulate-punctate apically. Body beneath finely sparsely punctate, the metasternum shining; the metasternal episternum with fine pustulae toward the anterior margin; the abdominal sternites dull, finely pustulate at the punctures, with fine transverse rugae toward the lateral margins. Pubescence inconspicuous, fine and sparse, subdepressed on the pronotum and elytra, more strongly so on the body beneath.

Female. Unknown.

Originally described from Banff, Alberta (type); Cochrane, Alberta; Creston, B.C.; Seattle, Wash. and Tollgate, Blue Mts., Ore. Additional specimens have been studied from Sanca, B.C., and Midday Valley, Merritt, B.C.

Phausis nigra R. Hopping

(Plate I, fig. 10. Plate II, figs. 8A, 8B, 8C)

Phausis nigra Hopping. 1937, Can. Ent., 69:89-90. *Phausis nigra* Fender. 1961, Univ. Wash. Pub. Biol., 16(3):43.

Piceous to black. Antennae and explanate pronotal margins yellowish brown, pronotum with an anterior pair of large translucent spots, these spots blackish medially due to head beneath showing through. Pubescence cinereous. Length 5 to 7 mm.

Male. Head finely closely punctured; eyes small, remote; antennae moniliform, extending to the middle of the metathorax, second segment short and transverse, third segment two and a half times as long as second, remaining segments progressively shorter and narrower, apical segment longer, the appendix short and fine, apically truncate. Pronotum subelliptical, wider than long, a line tangental to the middle of the sides meeting a produced line parallel with the base at an angle of about 70°, the anterior and lateral margins strongly reflexed, the sides becoming widely explanate toward the basal angles, the basal margin bisinuate, deeply guttered, hind angles finely denticulate; disc shining, finely sparsely punctured; anterior translucent spots impunctate, large and subreniform in outline; margins coarsely closely rugose punctate (in front of the translucent spots on the anterior margin). Scutellum spatulate, sparsely coarsely punctured. Elytra four times as long as the pronotum, feebly translucent, the side margins rather widely explanate from near the base to the apical third, strongly rugose. Body beneath and legs shining and finely sparsely punctured, the abdomen a little duller and with fine transverse rugae.

Described by Hopping from British Columbia: Trinity Valley (type locality), Midday Valley, Fernie and Vernon. Specimens have been examined from these additional British Columbia localities: Sanca and Creston.

Phausis skelleyi Fender

(Plate I, fig. 11. Plate II, figs. 9A, 9B, 9C)

Phausis skelleyi Fender. 1961, Univ. Wash. Pub. Biol., 16(3):42-43.

Brunneous to brownish black. The clypeus and apical halves of the mandibles testaceous, the reflexed margins of the pronotum paler than the convex median portion; an anterior pair of large transclucent spots; ultimate sternite, apical halves of the trochanters and apices and bases of the femora and tibiae obscurely paler. Pubescence brownish on the dorsal surface, cinereous ventrally. Length 5 to 6 mm.

Male. Head transversely concave between the eyes, elevated at the antennal sockets; eyes moderately large, remote; antennae submoniliform, compressed, extending to about the middle of the metathorax, the second segment short, transverse, the third segment three times the length of the second, segments three through ten of nearly equal length, progressively feebly narrowing, the eleventh ovate, the appendix minute, ovate. Pronotum transverse, broadly subelliptical, the anterior angles obsolete, the sides strongly obliquely arcuate, a line tangental to which meeting a produced line parallel to the base at an angle of about 55°, the base broadly bisinuate, the basal angles dentate; the apical and lateral margins anteriorly broadly reflexed, the lateral margins toward the basal angles broadly explanate, the basal margin narrowly reflexed medially, more so basally toward the sides; translucent spots large and approximate, subtriangular with the angles rounded to subreniform, finely sparsely punctured; reflexed lateral margins and the interval between the translucent spots of the anterior margin finely reticulate-punctate, the median convexity shining and finely sparsely punctured. Scutellum spatuate, apically rounded, the surface with a number of longitudinal rugae. Elytra nearly five times the length of the pronotum, rugose to reticulate-punctate basally, becoming more finely so apically, the explanate lateral margins sparsely, moderately pustulate. Metasternum shining, finely sparsely punctured, abdominal

sternites alutaceous, finely sparsely pustulate. Pubescence fine sparse and inconspicuous, thicker and more conspicuous on the legs.

Female. Unknown.

This species was originally described from McMinnville, Oregon (type), and Skye, Washington. Additional specimens have been seen from Newport, Ore., and Spring Creek, Baker Co., Ore.

KEY TO SPECIES

1. Abdominal sternites five and six each with a transverse luminous organ. 2

1′. Abdominal sternites five and six nonluminous although they may be paler in whole or in part. 4

2(1). Abdominal sternites five and six with luminous organs alone pale. 3

2′. Abdominal sternites five and six entirely pale. .... 3. *luminosa* Fend.

3(2). Antennae slender, terete; second segment elongate, as long as third. .... 1. *splendidula* L.

3′ Antennae stout, somewhat compressed, second segment short, transverse, less than half the length of the third. .... 2. *reticulata* Say.

4(1′). Brunneous to yellowish brown, species of eastern North America. .... 4. *inaccensa* Lec.

4′ Basic color piceous to black. 5

5(4′). Pronotum without transparent anterior spots and flavous with a large median black spot. .... 5. *dorothae* Fend.

5′ Pronotum with anterior transparent spots, one on each side. 6

6(5′). Pronotum with anterior transparent spots small and remote, separated by more than the width of one. 7

6′. Pronotum with anterior transparent spots large and approximate, separated by less than the width of one. 9

7(6). Pronotum entirely flavous. .... 6. *californica* Fend.

7′. Pronotum not entirely flavous. 8

8(7′). Pronotum flavous with a large black spot medially. .... 7. *riversi* Lec.

8′. Pronotum piceous to black, the reflexed margins brunneous, varying to the marginal bead only brunneous. .... 8. *marina* Fend.

9(6′). Pronotum rhomdoidal. .... 9. *rhombica* Fend.

9′. Pronotum subelliptical. 10

10(9′). A line tangental to the middle of sides meeting a produced line parallel with the base at an angle of about seventy degrees. .... 10. *nigra* Hopp.

10′. A line tangental to the middle of the sides meeting a produced line parallel with the base at an angle of about fifty-five degrees. .... 11. *skelleyi* Fend.

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Significance of the Scarcity of Early Pleistocene Glacial Deposits in the Western United States

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A CURIOUS though little remarked fact is that glacial deposits at least tentatively correlative with the four major stages of Pleistocene glaciation are exceedingly rare in the mountainous areas of the western United States. To date, they have been found in only three ranges, despite more than 50 years of investigations.

The common explanation for the scarcity of early Pleistocene glacial deposits in the western mountains is that long and vigorous erosion has removed all traces of such deposits in most localities. Another possible explanation, however, is that early Pleistocene glacial deposits never existed in some western ranges now bearing the impress of glaciation, because these ranges were below glacial snowline early in Pleistocene time and rose into snowline during Pleistocene time. This possibility seems not to have been considered seriously in this country, although a number of glacial geologists in Europe, more impressed than American geologists by the evidence of large amounts of uplift in Pleistocene time, consider it a satisfactory explanation for the slight degree of glaciation evident in some European ranges. Summarizing the European literature, Charlesworth (1957) writes: "Thus Pleistocene earth-movements explain why in the German Mittelgebirge, in the Mediterranean, including the Apennines, Sierra Nevadas, Atlas Mountains, Anatolia and the Balkans . . . only one glacial epoch and that the last is present."

Resume of Mountain Glaciation in the Western United States

The evidence of glaciation in the Rocky Mountain area, as summarized by Flint (1957), consists in general of three elements:

1. Young glacial deposits, showing fresh constructional topography and only slight weathering; referred to the Pinedale glaciation of late Wisconsin time.

2. Older drift, showing constructional forms much blurred by mass wasting and by cover of loess, distinctly weathered and frequently exhibiting a mature soil profile; referred to the Bull Lake glaciation of early Wisconsin time.

3. Patches of deeply weathered drift normally showing no traces of con-

structional forms, in many places lying on erosion surfaces hundreds to more than a thousand feet above present stream levels; originally referred to a Buffalo glaciation, now to one or more pre-Wisconsin stages of glaciation.

Work by Richmond (1957) has demonstrated the evidence of three pre-Wisconsin glaciations in the Wind River Mountains of Wyoming, the mountains of northern Idaho and Wyoming (Glacier National Park area), and the La Sal Mountains of Utah. The evidence consists of sheets of till that are separated by zones of weathering and mature soils. Richmond tentatively correlated the three pre-Wisconsin glaciations with the Nebraskan, Kansan, and Illinoian glaciations of the midcontinent.

A point to be stressed is that the evidence of three pre-Wisconsin glaciations has been found only in three of those mountainous areas that extended far higher into glacial snowline than the majority of the other glaciated areas.

We may examine two types of evidence to test the hypothesis that many ranges showing evidence of glaciation lay below glacial snowline early in Pleistocene time, or not as far above it as they do at present. The first is the heights of glaciated areas above glacial snowline. The second is the probable amount of uplift of the mountainous areas during Pleistocene time.

Heights of Glaciated Areas above Glacial Snowline

The heights that the glaciated ranges of the western United States extended above snowline, at least in Wisconsin time, are considered to equal the differences between summit elevations and the elevations of the lower cirque floors. The assumption that cirque floors and snowline coincide roughly is a fairly strong one that has been argued at length elsewhere (Flint, 1957; Charlesworth, 1957). The elevations of cirque floors accord well in any given range after allowing for expectable differences on opposite sides of ranges and northward decline in elevation (in the northern hemisphere) in long ranges.

Figure 1 shows the differences in elevation between summits and snowline, as shown by cirque floors, in 44 western ranges for which data are available (Flint, 1957). The range in differences in elevation shown for a number of the glaciated mountain areas reflects the differences in elevation of lower cirque floors on opposite side or northern and southern ends of individual mountain ranges.

The figure shows clearly the great differences in the heights of western mountains above snowline of glacial times, from an average of around 5000 feet in the Sierra Nevada to virtually zero on the Aquarious Plateau of Utah. More significantly, the figure shows that the highest summits of nearly half

the glaciated mountain areas extended less than about 2000 feet above snowline. If these mountainous areas rose as much as 2000 feet during Pleistocene time, about half of the areas that show evidence of glaciation would have

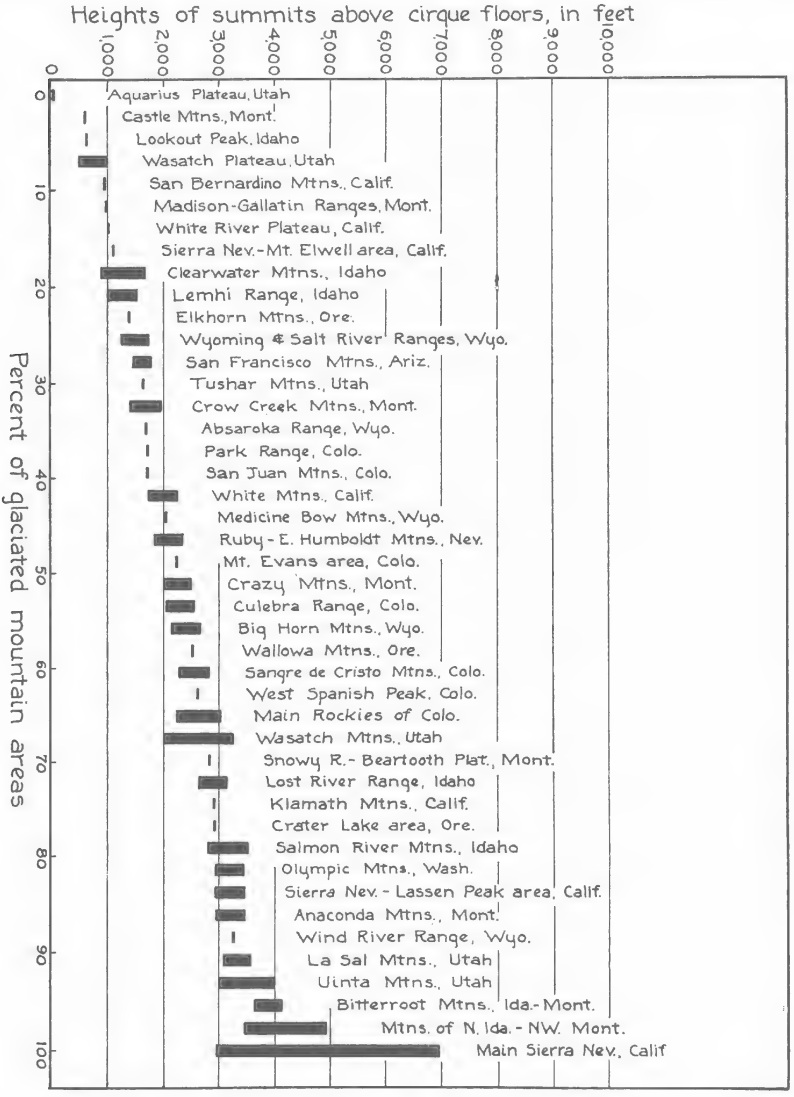

Figure 1. Differences in elevation between summits and snowline of glacial time, as determined from cirque floors, in 44 glaciated mountain areas in the western United States. (Data from Flint, 1957.)

been below snowline early in Pleistocene time, assuming that snowline had about the same elevation above sea level during the early glaciations as during the later glaciations.

Probable Amounts of Uplift during Pleistocene Time

It is now generally agreed that continental areas have risen considerably since Plio-Pleistocene time. According to Flint (1957) post-Pliocene uplift has raised the mean heights of the continents about 1600 feet, from below about 980 feet to around 2600 feet. The reported uplifts since Plio-Pleistocene time in many mountainous areas around the world are larger; they are rarely estimated at less than a few thousand feet (Flint, 1957; Charlesworth, 1957), and in the Himalayas have been estimated at around 13,000 feet by Hagen (1963).

Many ranges of the western United States have risen thousands of feet since late Pliocene time, according to those who have studied them. The Front Range of the Colorado Rockies has risen about 5900 feet (Wahlstrom, 1947); the San Juan Mountains of Colorado 3280 feet (Atwood and Mather, 1932); the mountains of western Montana "several thousand feet" (Pardee, 1950); and the Alaskan Coast Range as much as 5000 feet (Capps, 1931). Although estimates of uplift since late Pliocene time are lacking for most of the other ranges, it seems likely that they have risen at least the 1600 feet that Flint estimates for the continents as a whole, and probably considerably more.

There is a tendency on the part of some geologists to deny that the high surfaces of the western mountains indicate large uplifts. The upland surfaces, the argument runs, are the higher portions of pediments left isolated by erosion of the lower and once very extensive pediment slopes. According to this interpretation, the relief between upland surfaces and the lowlands has been caused by a change in stream regimen, from conditions under which graded streams widened out pediments and spread waste to conditions in which streams cut downward strongly.

Opposed to this concept that the present relief represents a change in process, not uplift, we may set not only the opinions of the many geologists who have reported large uplifts, but also the forcible evidence of uplift in some mountains. The uplift of around 5000 feet of the Alaskan Coast Range that Capps (1931) reports is based on the presence of sediments carrying Pleistocene marine fossils at that height. In California the exhaustive studies of Bull (1964) on segmented alluvial fans show convincingly that the Coastal

Range has risen probably "more than 2000 feet during and since the Coast Range orogeny," which is generally considered to be of middle to late Pleistocene age.

A more important question is: are the present high elevations of continents and mountains due primarily to large-scale uplift in Plio-Pleistocene or early Pleistocene time, or are they due to recurrent uplifting movements that began at those times?

The weight of the present evidence seems to indicate that intermittent uplifts continuing into the present are responsible for a major part of the total uplift of these areas since Plio-Pleistocene time. The surfaces of erosion that one commonly finds between uplands and modern lowlands tell a story of recurrent uplift rather than of one grand uplift early in Pleistocene time. Also, considerable uplift and erosion apparently occurred between such individual glaciations as can be recognized. As Richmond (1957) notes, deposits of pre-Wisconsin till in most places "cap high interstream divided or remnants of broad-valley erosion surfaces along the upper slopes of canyons," and "tend to be dissected from 200 to over 1,000 feet by modern trunk streams."

Here again some geologists may question whether the downcutting between glacial events necessarily signifies uplift. However, most geologists probably will prefer to believe that the cutting of valleys a thousand feet below old erosion surfaces, into strong rocks, signifies uplift rather than a change in stream regimen due to climatic fluctuation, at least until stronger evidence is introduced to support the latter theory.

The belief that present elevations are due to Pleistocene movements is fortified by the accumulating evidence, interestingly summarized by Charlesworth (1957), that all of Pleistocene time has been a revolutionary period, not merely the beginning of it. Although the Rockies and most of the ranges farther west do not show the activity registered in California, where mid-Pleistocene sediments have been folded in the Coast Range orogeny (Bull, 1964) and the San Bernardino Mountains are now rising at a rate of two feet per hundred years (Gilluly, 1949), they certainly are not dead. For example, from tree-ring data Pardee (1950) estimated a movement of 10 to 30 feet along the fault at the foot of the Madison Range in western Montana since 1770.

The available data therefore suggest most strongly that the western ranges in the United States have risen a few to several thousand feet since Plio-Pleistocene time, and that much of this total uplift is due to recurrent movements through Pleistocene time, which are continuing in certain areas even now.

Summary and Conclusions

To the present, evidence of glaciation in all four glacial stages of the Pleistocene has been found in only three of the mountainous areas of the western United States that extend much further above glacial snowline than average. This scarcity of early glacial deposits may very well be interpreted as showing that many mountains bearing the impress of glaciation were uplifted into glacial snowline during the Pleistocene.

In about half of the glaciated areas for which there are data the summits stand from barely above to little more than 2000 feet above glacial snowline as determined from elevations of lower cirque floors. Uplift of the mountains during Pleistocene time probably equalled or exceeded 2000 feet on the average. Therefore mountain areas that extended only a few hundred to 1000 feet or so above glacial snowline during the Wisconsin glaciation almost certainly were below glacial snowline during one or more of the earlier glaciations. To take an actual example, the San Bernardino Mountains of California, which stood slightly less than 1000 feet above snowline in Wisconsin time, are rising two feet per hundred years (Gilluly, 1949) and at this rate would have been 1000 feet lower and below snowline only 50,000 years ago. Other ranges were not so high above glacial snowline in the early Pleistocene—which includes both Kansan and Nebraskan glaciations—as in the late Pleistocene, and consequently were then only lightly glaciated, leaving less evidence to survive the extensive erosion since Kansan time.

If the foregoing hypothesis is true, early glacial deposits should not be expected in a considerable percentage of the glaciated ranges of the western United States because they were below glacial snowline in early Pleistocene time. As a corollary, periglacial deposits such as outwash and loess of early Pleistocene age will also be missing in the vicinity of such ranges, and also the evidence in lake beds of environmental changes accentuated by the waxing and waning of nearby glaciers.

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Artificial Ripening of Grand Fir Cones

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THE DEMAND for grand fir (*Abies grandis* (Dougl.) Lindl.) for artificial reforestation of cutover areas is growing rapidly. Poor viability of collected seed is a critical factor in artificial regeneration and necessitates use of large quantities of expensive seed to provide an adequate number of seedlings. Collection of immature cones may be a major cause of poor viability. Artificial ripening of immature cones has helped improve germination of other conifer species. Ching (1960) pointed out the special importance of the maturity factor for grand fir, and the influence of maturity on viability.

The study reported in this paper was conducted in 1961 in northern Idaho to test the effects of several artificial cone-ripening techniques on seed maturation, seed germinability, and seedling vigor. A major goal was to explore the possibility of lengthening the cone-collection period for the species.

Experimental Methods

Cone Collection and Selection

Cones were collected from grand fir trees in a mature, mixed conifer stand in the Deception Creek area of the Coeur d'Alene National Forest. The stand is on a northerly slope at about 3200-feet elevation; this habitat is ecologically characterized as a *Thuja-Tsuga Pachistima* type (Daubenmire, 1952). Cones were collected six times at 10-day intervals from July 25 to September 13, 1961, by felling two or three trees on each collection date. The cones were covered with damp muslin to prevent desiccation during transport to the Deception Creek Experimental Forest.

Cones were sorted after arrival at the Experimental Forest headquarters. On each collection date, 200 sound cones were selected for use in the artificial ripening treatments. Measurements and morphological observations were made on 20 additional sound cones from each collection to develop a maturity index (Pfister, 1966). Cones showing external symptoms of insect infestation were studied to determine the kinds and number of insect larvae present and the amount of seed destroyed (Pfister and Woolwine, 1963). Mechanically damaged cones were discarded.

Artificial Ripening Treatments

The 10 storage treatments used for the cones are listed and briefly described below. Treatments 1 through 9 were in screened enclosures set in a small stream.

Treatment conditions	*Treatment numbers*
A. Exposed outdoor enclosure (received 70 per cent of full sunlight)	
1. Cones attached to branches	
a. Branch base in water (stream)	1
b. Branch base in nutrient solution (a modified Hoagland nutrient solution was used)	2
2. Detached cones	
a. Basal end in one-half inch of water	3
b. Basal end in one-half inch of nutrient solution	4
B. Shaded outdoor enclosure (received 5 per cent of full sunlight)	
1. Cones attached to branches	
a. Branch base in water (stream)	5
b. Branch base in nutrient solution	6
2. Detached cones	
a. Basal end in one-half inch of water	7
b. Basal end in one-half inch of nutrient solution	8
c. Stored in 4 inches of damp peat moss	9
C. Control (detached cones on racks in shed)	10

Each storage treatment for each dated cone collection was replicated on 10-cone groups. Cones from individual trees were apportioned among treatments. Nutrient solution containers were surrounded by continuous streamflow to maintain temperatures equivalent to those of the water treatments, and solution was added as often as necessary to maintain the desired level. The cut ends of branches were trimmed at 10-day intervals to prevent plugging of conductive tissue by fungi.

During the treatment period (July 25 - September 12), average maximum air temperatures were 83° F. in the exposed enclosure, 68° F. in the shed and shaded enclosure, and 78° F. in the nearby Experimental Forest standard weather station. Average minimum air temperatures differed only slightly from the 44° F. reported by the weather station. Average daily stream temperatures decreased from 55° to 42° F. during the period; the diurnal fluctuation was only about 6 degrees. Within the peat moss, diurnal temperatures varied more widely (about 14 degrees), but the average temperatures approximated those of the stream.

When the ripest cones in any dated collection had matured to the point

that seeds began to fall out, all cones collected on that date were removed from their treatment and placed on racks in the shed with the control treatment to dry. Cones stored in damp peat moss (treatment 9) did not dry; so they were moved to a heated building on October 15.

Seed Extraction and Storage

On October 25, after 6 to 12 weeks of cone storage, seeds were screened to remove the scales, hand-rubbed to remove the seed wings, and cleaned with a small fan. Cleaning did not remove the empty seeds. The cleaned seed was then stored at about 1° C. for approximately one month. Six 100-seed samples from each of the 50 combinations of treatment and collection date were stratified between layers of damp peat moss at about 1° C. for 26 days prior to the germination test.

Seed Weight, Germination, and Seedling Vigor

Seed weighing and germination tests began in early January. Fresh weight was determined for two 100-seed samples of stratified and unstratified seed from each treatment-collection date combination. Dry weight and moisture content were determined for one 100-seed sample of unstratified seed from each treatment-collection date combination.

Germination tests were conducted on six 100-seed samples of stratified and two 100-seed samples of unstratified seed from each treatment-collection date combination using plastic petri dishes containing "Sponge Rok." (Material produced by Paramount Perlite Co., Paramount, California. Trade names given here are for purposes of identification only and do not constitute an endorsement by the U.S. Forest Service.) Alternating temperatures of 20° C. (16 hours daily in the dark) and 30° C. (8 hours daily with light) were maintained during these tests. Germination counts were made at two- or three-day intervals for 30 days. Ungerminated seeds were cut to determine whether they were filled, empty, or woody. If filled, tetrazolium chloride was used to establish apparent viability.

Ten seedlings, approximately five days old, were selected to represent each sample of stratified seed. Length of each seedling was measured, and each 10-seedling group was weighed to provide means for comparing early vigor.

Results

Seed Germination

Germinative capacity (includes those seeds that actually germinated plus the seeds—generally less than 2 per cent—that the tetrazolium test indicated

were viable) of seeds from the control treatment increased as collection dates approached the time of natural seedfall (Table 1). Cones collected prior to August 15 yielded no germinable seed under control storage conditions. Production of germinable seed generally increased from August 15 until and including the final collection, when natural seedfall was beginning. Germination did not level off prior to maturity, as is characteristic of some species. Apparently seeds continued to mature until natural seedfall. Unstratified seed from the August 15 collection germinated very slowly, but for later collections the rate of germination was uniformly rapid.

The general increase in germinative capacity as the season advanced is highly significant statistically when data from all treatments are pooled. ("High significance" and "significance" refer to statistical significance at the 1 and 5 per cent levels, respectively.) The general decrease in germinative capacity of seed collected on August 24 is presumably due to large chance-variation among sample trees since different trees were used for each collection date.

Artificial ripening treatments were generally beneficial. All treatments except storage in peat moss produced significantly more germinable seed than did the control treatment. Peat moss storage conditions reduced germination significantly in collections made after August 15. Detached cones produced significantly more germinable seed than did attached cones.

The relative increase in germination capacity due to treatment varied by collection date (Figure 1). Treatment 8 was generally the best, and, for collections made after August 15, treatment 9 was the poorest. Seed collected on August 15 responded best to all treatments. Artificial treatments all produced seed of higher germinative capacity than did the control treatment.

TABLE 1.
GERMINATION CAPACITY AND RATE OF GERMINATION BY COLLECTION DATE FOR THE CONTROL TREATMENT

	Stratified seed	*Unstratified seed*	
Collection date	*Germination capacity*	*Germination capacity*	*Rate of germination*
	Per cent	*Per cent*	*Days*[1]
July 25	0.0	0.0	- -
August 4	0.0	0.0	- -
August 15	30.0	31.0	24
August 24	28.5	32.0	9
September 3	52.0	59.0	11
September 13	72.3	68.0	11

[1] Number of days required to reach 50 per cent of germination capacity.

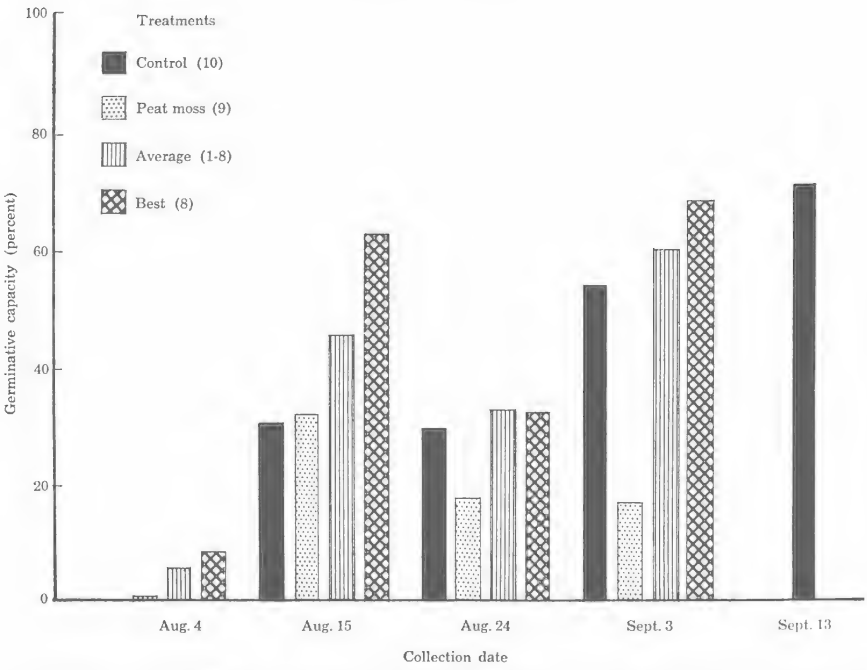

Figure 1. The effect of treatment on germinative capacity for each collection date.

The 62.5 per cent germination of seed collected on August 15 and subjected to treatment 8 is only 9 per cent less than that for naturally mature seed collected September 13.

Collection date and artificial ripening treatments had little influence on rate of germination of nonstratified seed (Table 3). The small differences appear to be related to germination capacity—treatments that increased capacity also increased rate. Treatment 9 (peat moss) was an exception: capacity decreased, but germination was rapid.

Seed Weight and Moisture Content

Seed weight increased as collection dates approached maturity. For the control treatment, average oven-dry weights were:

Collection date	*Grams/100 seeds*
August 4	1.32
August 15	1.74
August 24	1.75
September 3	2.45
September 13	2.67

TABLE 2.

GERMINATION CAPACITY BY COLLECTION DATE AND TREATMENT
(Each figure represents the average of eight 100-seed lots)

Treatment	Collection date[1]				Average
	August 4	*August 15*	*August 24*	*September 3*	
	Per cent of total seeds				
(1) Sun, Attached, Water	4.2	37.6	32.8	60.2	33.7
(2) Sun, Attached, Nutrients	2.9	32.6	31.9	54.0	30.3
(3) Sun, Detached, Water	10.4	50.1	33.1	59.6	38.3
(4) Sun, Detached, Nutrients	4.4	48.2	33.4	60.2	36.6
(5) Shade, Attached, Water	3.9	39.1	30.5	57.4	32.7
(6) Shade, Attached, Nutrients	3.1	42.1	36.0	55.1	34.1
(7) Shade, Detached, Water	6.9	51.8	32.0	62.9	38.4
(8) Shade, Detached, Nutrients	8.5	62.5	32.1	68.2	43.0
(9) Damp peat moss	0.6	31.9	18.0	16.8	16.8
(10) Control	0.0	30.3	29.4	53.8	28.3
Average	4.5	42.6	30.9	54.9	33.2

[1] No seed from the July 25 collection germinated.

TABLE 3.
RATE OF GERMINATION FOR NONSTRATIFIED SEED BY COLLECTION DATE AND TREATMENT

Treatment	*Collection date*[1]			*Average*
	August 15	*August 24*	*September 3*	
	Days[2]			
1	12.3	12.2	10.6	11.7
2	18.6	10.0	11.0	13.5
3	11.2	11.0	10.0	10.8
4	11.2	9.8	10.4	10.5
5	8.8	11.0	8.8	9.5
6	8.6	11.2	10.2	10.0
7	8.0	11.7	9.7	9.8
8	8.5	10.2	10.0	9.6
9	9.6	7.4	7.2	8.1
10	24.1	9.0	11.0	14.7
Average	12.1	10.4	9.9	10.8

[1] Germination capacities from seed collected August 4 were too low to provide meaningful rate-of-germination values.
[2] Number of days required for nonstratified seed to reach 50 per cent of germinative capacity.

This increase in weight corresponds with the increase in germination capacity, including the relatively low value for the August 24 collection.

Seed weight also varied by treatments. (Seed weights were not tested statistically because they were determined for only one replication.) Treatment averages, for all collection dates, ranged from 1.80 to 2.30 grams per 100 oven-dry seeds. Treatments 1, 2, and 10 (low germination) had the lowest average weights, while treatments 3, 4, 7, and 8 (above-average germination) were above average in weight. Treatment 9 was the exception—low germination but average weight.

Seed from early collections retained a higher moisture content (11.0 per cent) than the seed from late collections (8.2 per cent). Cone-storage conditions had no apparent effect on this characteristic.

Seedling Vigor and Weight

Average total length, by treatments, of seedlings approximately five days old ranged from 36.7 to 41.4 millimeters. Treatment 9 (peat moss) produced the shortest seedlings, chiefly because of the detrimental effects of seed mold. Other treatments apparently did not affect length of seedlings; neither did differing dates of collection.

Average seedling weight was greater for the later collections and, like germination capacity, appeared to be related directly to seed weight, which showed the same trend.

Discussion and Conclusions

Total number of seeds was used as the base for calculating germinative capacity because the proportion of empty, woody, and filled seeds varied with collection date and treatment. Many apparently normal seeds from early collections shriveled before the germination tests, and there was no clear distinction between woody seeds and empty seeds.

Germinability of grand fir seed improved until the time of seed dispersal. This behavior differed somewhat from the usual pattern of coniferous seed maturity: rapidly increasing germinability in early collections and then leveling off prior to seed dispersal.

The effect of storage treatments on production of germinable seed shows that early collection and ripening during storage can lengthen the cone-collection period without seriously reducing seed viability.

Treatments (except the control) were designed to keep cones moist or in more nearly natural condition (attached). The nutrient solution was included to determine whether cones had completed nutrient accumulation at the time of early collection, and if not, whether artificial ripening conditions would allow completion. Nutrient solution seemed to benefit detached cones stored in the shade. Perhaps maximum movement of organic materials into the cone occurred, but evidence was insufficient to confirm this hypothesis; biochemical tests would be needed to trace nutrient supply and utilization.

Seed weight and germinability both indicate that cone-storage conditions provided in this study were sufficiently favorable to facilitate continued movement of organic materials to the seed. Tests have shown that favorable cone-storage conditions promote movement of nutrients in Douglas-fir (Rediske, 1961; Silen, 1958) and noble fir (Rediske and Nicholson, 1965).

Seed from cones stored in peat moss (treatment 9) was seriously damaged by fungi and, possibly, by anaerobic conditions caused by excessive moisture. However, seed weight did increase, and maturation probably progressed satisfactorily during the early part of storage. The rapid rate of germination of seed from cones stored in peat moss may have resulted from storage conditions that simulated stratification. Franklin (1965) also found that storage in peat moss harmed noble fir cones, although Silen (1958) had used it successfully to ripen immature Douglas-fir cones artificially. Careful control of temperature and moisture evidently is needed to use this technique effectively.

Storage of attached cones was less effective than storage of detached cones. Resin blockage in the branches may have hindered water movement.

Also, because storage of attached cones is cumbersome, it would be desirable to exclude this method from practical consideration.

Storage in the sun appeared detrimental to detached cones; this indicated that cool, moist conditions are preferable. However, sufficient aeration must be provided to prevent development of fungus.

The August 24 collection yielded seed having relatively low germinability, and treatments resulted in little increase. Perhaps one or more trees that were selected for collection on that date were either ineffectively pollinated or were inherently poor-quality seed producers. Cones were evidently quite close to maturity since the treatments had little effect. Franklin (1965) also could not explain a similar depression in germinability of noble fir seed from one collection date although cones were collected from the same trees on all dates.

Results of this study clearly indicate that refinement of some artificial ripening techniques could successfully lengthen the collection period, and provide methods for ripening cones collected prematurely. In the future, as problems in seed procurement become more critical, further tests may be needed to develop more efficient methods for commercial use.

Summary

Grand fir cones collected at 10-day intervals from July 25 to September 13, 1961, from one northern Idaho location were used to study artificial ripening techniques in which cones were stored under 10 treatment conditions.

As collection dates approached the time of natural seedfall, seed germinability increased; germinability did not level off as it does for most species of conifers. Storage conditions designed to encourage artificial ripening (treatments 1 to 9) were generally beneficial; they resulted in increased germination and produced heavier seed than those from detached cones stored in racks in a shed (control treatment). Immature seed (collected August 15) from all treatments except the control germinated quite rapidly. Data on development of five-day-old seedlings showed little effect from either collection date or storage treatment.

Storing detached cones in the shade with their bases in nutrient solutions or water provided the greatest increase in germination. Storage in damp peat moss was the only treatment that reduced germination—an effect attributed to anaerobic conditions and development of injurious fungi. However, increased seed weight indicated that storage in peat moss might be useful to ripen cones if proper conditions were maintained.

The results of this study show that storage of cones under proper condi-

tions can foster artificial ripening. If the techniques reported here are adapted for commercial use, the effective cone-collection period for grand fir can be lengthened two to four weeks.

Acknowledgments

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Vegetation Following Slash Fires in One Western Oregon Locality

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BROADCAST BURNING of logging slash following clearcutting is a common forest management practice on the west side of the Cascade Range. A study (Morris, 1958) to measure effects of slash burning on fire hazard and on revegetation of conifers and other plants was begun in 1946 in the Douglas-fir subregion of Oregon and Washington. In this paper, some ecological effects of slash fires near Oakridge, Oregon, will be considered, using data from a small portion of the study area.

Before slash burning, pairs of adjacent, rectangular plots, about one-fourth acre each, were selected. One plot of each pair was burned with the rest of the clearcut unit. The other plot was left unburned to provide a control. If less than two-thirds of the ground was blackened on a burned plot, or if an especially hot or fast-spreading fire burned a portion of the proposed unburned plot, the pair was rejected. These rejections tended to leave for study only those plots that had medium intensity slash fires. Thirteen pairs of plots in the Oakridge area survived rejections.

A pair of plots was always selected on the same slope, with the same aspect and similar slash. Pairs range between elevations of 2250 to 3750 feet, slopes of 0 to 40 per cent, and six aspects: N., S., W., NE., SE., and SW. The plots are at an average distance of 350 feet from the nearest conifer seed source; the closest pair is within 50 feet, the farthest 1000 feet from standing timber. One pair receives a little afternoon shade; 12 pairs are in the open. Most pairs are at midslope, but one is in a creek bottom. The timber type prior to logging was old-growth Douglas-fir *(Pseudotsuga menziesii)*[1] with western hemlock *(Tsuga heterophylla)* and true fir *(Abies* spp.) associates. The pair located in a creek bottom had a Douglas-fir—western redcedar *(Thuja plicata)* stand. Site class, or productivity of the plots for tree growth, ranged from site II to site IV.[2]

[1] Authorities used for common and scientific names are Little (1953) for trees and some shrubs and Kelsey and Dayton (1942) for other vegetation.

[2] Site class is determined by the relation between total height of dominant or codominant trees and tree age. Site class I is best, site class V is poorest.

One or more plots were burned each year from 1946 to 1951. Cover records beginning in 1947 were collected annually to 1953, except that six of the older plots were skipped in 1952. After a nine-year interval, the final examination was made in 1962.

Vegetation was placed in three categories: conifer, brush, and herbaceous. Pacific yew *(Taxus brevifolia)* and all broadleaf tree species were considered brush.

Conifer Stocking

Conifer stocking was estimated by per cent of 4-milacre subplots having one or more naturally established conifer seedlings 6 or more inches high. Twenty-five subplots were examined in each burned and unburned plot, except at last examination when 12.5 subplots were examined.

During the first few years, unburned plots had significantly greater stocking than burned plots (Figure 1). The records show that only a few of the seedlings on the unburned plots became established before the logging. By the seventh year, however, burned plots caught up with the unburned; both burned and unburned plots then had about 60 per cent of the 4-milacre subplots stocked. The 11- to 16-year examination showed that both burned and unburned plots still had about 60 per cent stocking. By this time, the trees ranged from 6 inches to 25 feet.

In addition to stocked subplot analysis, in which all commercially important

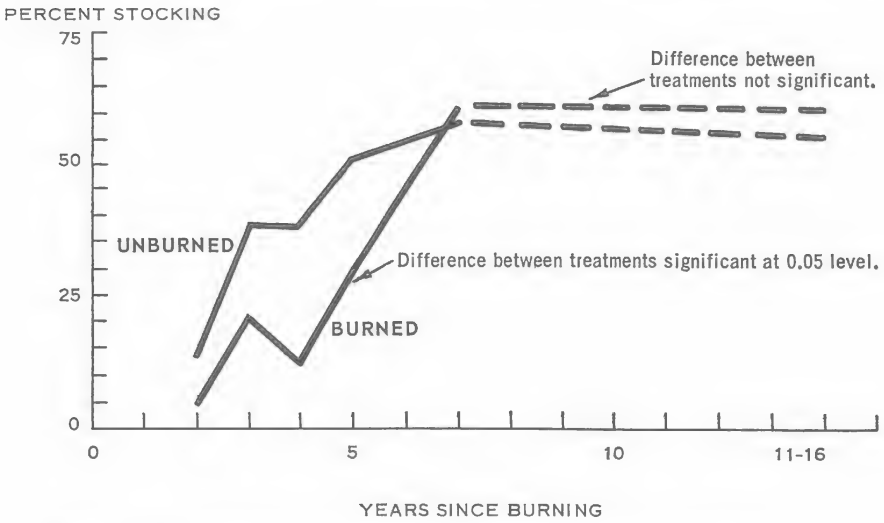

Figure 1. Conifer stocking on 13 pairs of burned and unburned plots.

species were recorded alike, a comparison was made of numbers of seedlings by species for burned and unburned plots. General differences between plots were similar to those noted in the stocking comparison. The most numerous species on both unburned and burned plots was Douglas-fir.

Brush Cover

The proportion of available growing space (rock, wood, etc. were not considered available growing space) shaded by brush was estimated by a vertical projection of the brush canopy. These estimates were made on the same subplots used for conifer-stocking estimation. The 4-milacre subplots were visually divided into quadrants, and an estimate of available growing space shaded by brush species was recorded for each quadrant. Then, the proportion of brush cover by individual species was estimated and recorded for each quadrant. As various layers or stories of canopy developed, the estimating system tended to obscure the amount of cover at higher densities. For example, a closed canopy of a low-brush species and a closed canopy of a taller-brush species would be recorded as 100 per cent total shade—not 100 per cent shade by one and 100 per cent shade by the other.

There was significantly more brush on unburned plots for the first five years; however, by seven years, differences were no longer significant (Figure 2). Total cover ranged from 1 per cent on burned and 6 per cent on unburned plots after two years to about 40 per cent cover on both by 11 to 16 years.

Proportion of cover by individual species was also studied at different periods after burning. Since amount of shade depends on size of plant, frequency of occurrence should give a more sensitive measure than shade cover to show effects of fire on species composition. Frequency of occurrence, however, showed essentially the same relation between species as shown by amount of shade cover.

Apparently, the first brush species to become dominant is most likely to remain dominant for at least 10 years. On 54 per cent of burned samples, the brush species dominant two years after burning was still the major species 11 to 16 years after burning. On 69 per cent of unburned samples, initial dominant species of brush were still dominant at the last examination.

Individual brush species exhibited definite responses to treatment (Table 1). Ceanothus (includes both snowbrush ceanothus *(Ceanothus velutinus)* and varnishleaf ceanothus *(C. velutinus* var. *laevigatus)*) conspicuously dominated burned plots but covered very little of the unburned. Blueberry elder *(Sambucus glauca)* and hairy manzanita *(Arctostaphylos columbiana)* provided more cover on burned plots than on unburned plots, although they occupied

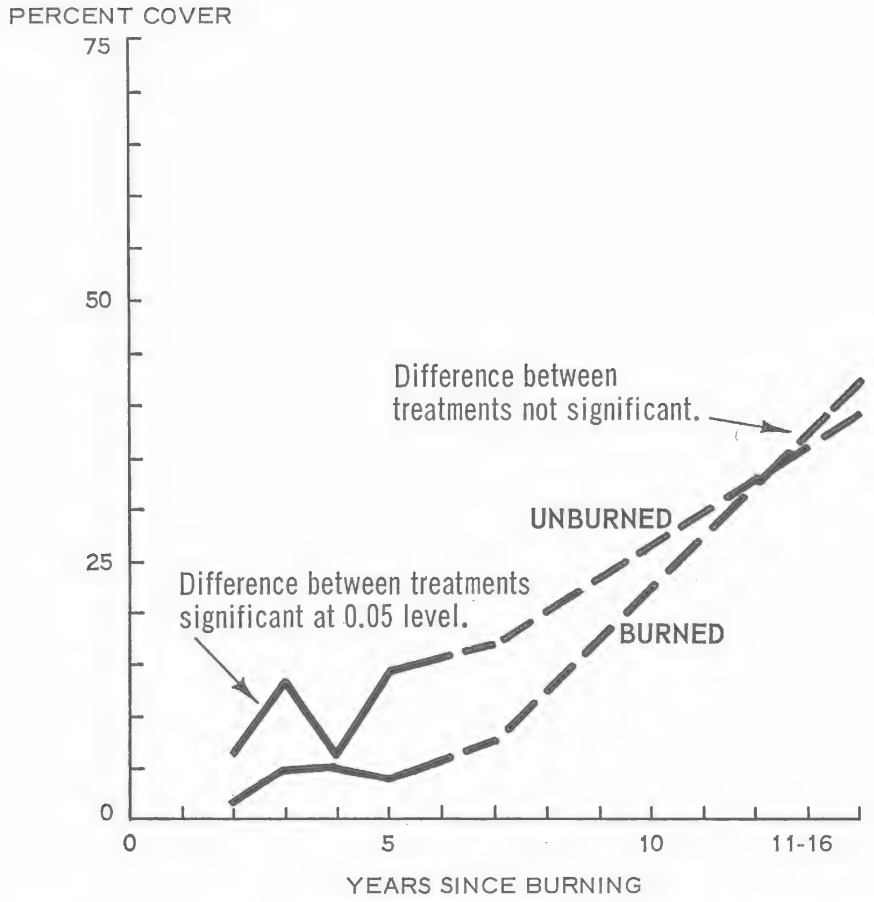

Figure 2. Per cent of ground shaded by brush on 13 pairs of burned and unburned plots.

a small proportion of the area. Pacific yew and blueberry *(Vaccinium* spp.), including red whortleberry *(V. parvifolium),* occurred rarely on burned plots, but both were commonly found on unburned plots. However, red whortleberry is often found on burned areas in the northern Cascade Range and in the Coast Ranges of Oregon. Pacific rhododendron *(Rhododendron macrophyllum)* and salal *(Gaultheria shallon)* were also found mainly on unburned plots. Vine maple *(Acer circinatum)* provided little more shade on unburned than on burned plots. By 11 to 16 years after burning, vine maple litter had formed dense mats on the ground (which could severely limit the occurrence of any other vegetation), but ceanothus litter had not formed dense mats

TABLE 1.

PER CENT OF BRUSH SHADE COVER FOR EACH MOST COMMON BRUSH AND HERBACEOUS SPECIES ON 13 PAIRS OF PLOTS AFTER SLASH BURNING; 1962 EXAMINATION[1]

Species	*Burned plots*	*Unburned plots*
Brush:		
Snowbrush ceanothus *(Ceanothus velutinus)* and Varnishleaf ceanothus *(C. velutinus* var. *laevigatus)*	55.4	3.3
Pacific rhododendron *(Rhododendron macrophyllum)*	4.9	30.5
Vine maple (*Acer circinatum*)	11.7	17.9
Salal *(Gaultheria shallon)*	2.5	11.7
Golden chinkapin (*Castanopsis chrysophylla*)	6.3	5.4
Cherry *(Prunus* spp.)	3.4	7.4
Blueberry *(Vaccinium* spp.)	.4	5.8
Cascades mahonia *(Mahonia nervosa)*	2.2	2.5
Western thimbleberry *(Rubus parviflorus)*	2.4	1.7
Pacific yew *(Taxus brevifolia)*	0	4.4
Hairy manzanita *(Arctostaphylos columbiana)*	3.2	.3
Willow *(Salix* spp.)	.5	1.4
Blueberry elder *(Sambucus glauca)*	.7	.1
Miscellaneous[2]	6.4	7.6
Total	100.0	100.0
Herbaceous:		
Trailing blackberry *(Rubus macropetalus)*	30.7	22.0
Willowweed *(Epilobium* spp.)	28.4	27.4
American twinflower *(Linnaea borealis* var. *americana)*	1.5	20.8
Modest whipplea *(Whipplea modesta)*	10.8	7.2
Cerastium *(Cerastium* spp.)	5.8	7.9
Peavine *(Lathyrus* spp.)	5.0	2.2
Lupine *(Lupinus* spp.)	1.9	1.4
Grasslike plants *(Gramineae* and *Cyperaceae)*	2.5	.6
Western starflower *(Trientalis europaea* var. *latifolia)*	2.1	.6
Western bracken *(Pteridium aquilinum* var. *pubescens)*	.8	.3
Bunchberry dogwood *(Cornus canadensis)*	0	.8
Miscellaneous[2]	10.5	8.8
Total	100.0	100.0

[1] Basis: 1300 milacre quadrants on 13 pairs of burned and unburned plots.
[2] Includes small amounts of the above species and those in Table 2.

(allowing other vegetation to be established). Few species of brush or herbs grew under vine maple, but some did grow under ceanothus. Brush species that were occasionally observed on the plots but were not large enough or dense enough to contribute to shade estimates are listed in Table 2.

TABLE 2.

OCCURRENCE OF LEAST COMMON BRUSH AND HERBACEOUS SPECIES ON 13 PAIRS OF PLOTS AFTER SLASH BURNING; 1962 EXAMINATION[1]

Species	*Burned plots*	*Unburned plots*
Brush:		
Whitebark raspberry *(Rubus leucodermis)*	X	X
Pacific madrone *(Arbutus menziesii)*	X	X
Rose *(Rosa* spp.)	X	X
Common snowberry *(Symphoricarpos albus)*	0	X
Currant *(Ribes* spp.)	X	X
Gooseberry *(Ribes* spp.)	X	X
Red alder *(Alnus rubra)*	0	X
Black cottonwood *(Populus trichocarpa)*	0	X
Mountain-ash *(Sorbus* spp.)	0	X
Cascara buckthorn *(Rhamnus purshiana)*	0	X
Creambush rockspirea *(Holodiscus discolor)*	X	0
Cutleaf blackberry *(Rubus laciniatus)*	X	0
Herbaceous:		
Hawkweed *(Hieracium* spp.)	X	X
Cudweed (*Gnaphalium* spp.)	X	X
Common pearleverlasting *(Anaphalis margaritacea)*	X	X
Thistle *(Cirsium* spp.)	X	X
Solomonplume *(Smilacina* spp.)	X	X
Trefoil foamflower *(Tiarella trifoliata)*	0	X
Western swordfern *(Polystichum munitum)*	X	X
Bedstraw *(Galium* spp.)	X	X
Groundsel *(Senecio* spp.)	X	0
Ladyfern *(Athyrium filixfemina)*	X	X
Violet *(Viola* spp.)	X	X
Deerfoot vanillaleaf *(Achlys triphylla)*	0	X
Inside-out flower *(Vancouveria hexandra)*[2]	0	X
British Columbia wildginger *(Asarum caudatum)*	0	X
Oregon tea *(Satureja Douglasii)*[2]	X	0
Trillium *(Trillium* spp.)	X	0
Oxalis *(Oxalis* spp.)	X	0

[1] Species observed on plots but not shading enough area to be tallied.
[2] Common and scientific names from: Gilkey, Helen. Handbook of northwest flowering plants. Ed. 2, 414 pp., illus. Binfords & Mort, Portland, Oreg. 1961.

Herbaceous Cover

Total area shaded by herbaceous species was similar for burned and unburned plots (Figure 3), but there were differences in species composition (Table 1). Eleven to 16 years after logging and burning, trailing blackberry *(Rubus macropetalus)* was the most common species found on both burned and unburned plots, but it shaded more of the burned. Willowweeds *(Epilobium* spp.), including fireweed *(E. angustifolium),* were also common throughout the study area and shaded burned and unburned plots equally. This was expected, as the spreading habit of willowweeds is well known. American twinflower *(Linnaea borealis* var. *americana),* which is common in uncut

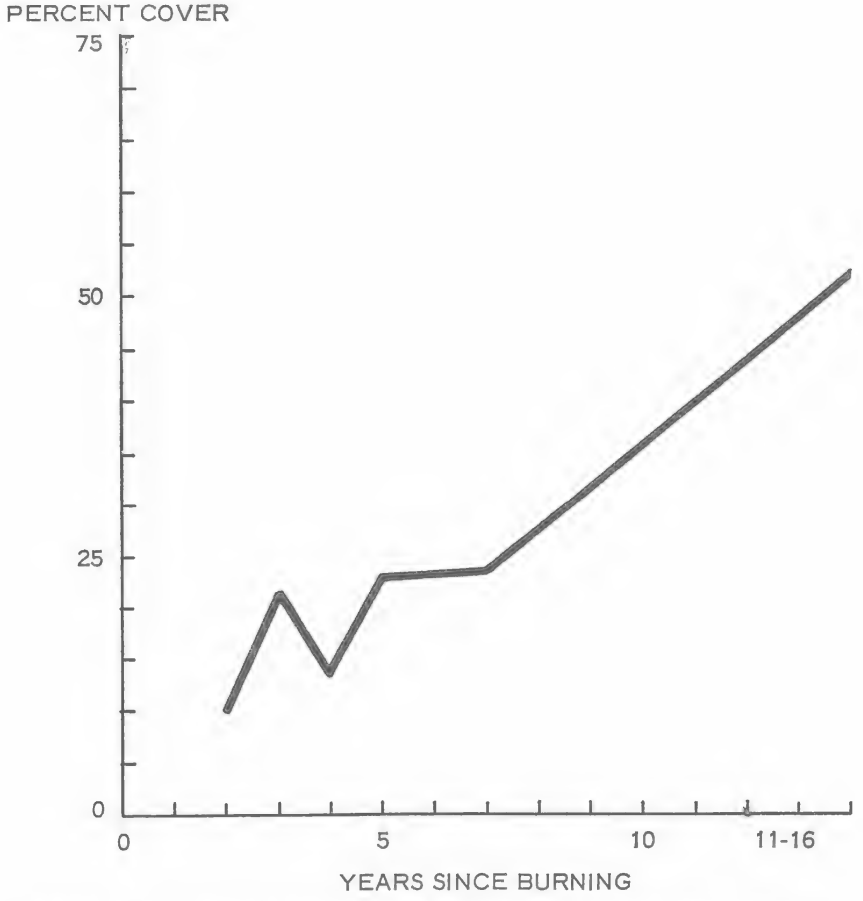

Figure 3. Per cent of ground shaded by herbaceous plants on 13 pairs of burned and unburned plots.

stands, shaded 14 times more area on unburned than on burned plots and was the third most common herbaceous plant (after trailing blackberry and willow-weeds).

Summary

Frequent examinations of 13 pairs of plots near Oakridge, Oregon, during the first 11 to 16 years following slash burning, showed some effects of burning logging slash. Significantly more conifer reproduction was found on unburned plots for the first six years following slash burning. However, by seven years, there was no longer a significant difference between conifer stocking on burned and unburned plots.

Significantly more brush covered unburned plots than burned plots for only the first five years following burning; by seven years the differences in brush cover were no longer significant. Snowbrush and varnishleaf ceanothus created dense shade on burned but very little on unburned plots. Pacific rhododendron grew in much greater quantities on unburned than on burned areas. Several other brush species grew more frequently on either burned or unburned plots. Total amount of cover of herbaceous plants was similar for both burned and unburned plots, but species composition differed. American twinflower covered much of the unburned area, but little of the burned. Trailing blackberry shaded more of the burned than the unburned area.

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CONTENTS

Geology of the Columbia River Gorge. *Ewart M. Baldwin* 121
Weather and Climate of the Columbia Gorge. *Robert E. Lynott* 129
The Flora of the Columbia River Gorge. *LeRoy E. Detling* 133
Amphibians and Reptiles. *Robert M. Storm* 138
Mammals and the Influence of the Columbia River Gorge on Their Distribution. *Kenneth Gordon* 142
The Annual Production of the Whitefishes *Coregonus clupeaformis* and *C. nasus* in Teslin Lake, British Columbia. *R. V. Boughton* and *W. A. Clemens* 147
Effect of Charcoal on Germination of Douglas-fir Seed. *Steven de Keijzer* and *Richard K. Hermann* 155
Mylodon harlani from Le Grande, Oregon. *Charles W. Quaintance* 164

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Geology of the Columbia River Gorge

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THE COLUMBIA River Gorge is a region of rugged beauty readily accessible by railroads and highways on both sides of the river. The gorge formed when the river maintained its course through a rising Cascade Range (Figure 1).

The geology of the gorge has been described in picturesque language in a well-illustrated report by Ira Williams (1916). Bretz (1925) and Bretz, Smith, and Neff (1956) described some of the effects of a late Pleistocene flood of enormous magnitude that swept down the gorge. Allen (1932), Hodge (1938), and Lowry and Baldwin (1952) described aspects of the geology of the gorge area. Trimble (1963) dealt with the western end, and Baldwin (1964) summarized the geology with illustrations of some of the salient features.

Stratigraphy

The oldest formation crops out along the north bank of the river near Camas and Washougal. It consists of basalt flows, breccias, and tuffs which Lowry and Baldwin (1952) considered to be an extension of the late Eocene Goble Volcanics. Trimble (1963: 11) included them in the lower part of his Skamania Volcanics. They are characteristically similar in position and lithology to the Clarno Formation of central Oregon.

The Eagle Creek Formation lies unconformably upon the extrusive basalt. It crops out between Horsetail Falls and Wind-Shellrock Mountains and in the lower part of the valleys of Eagle, Tanner, and Moffett creeks and along the north slope of the gorge beneath Mt. Hamilton. This formation is composed of mudflows, which probably formed when heavy rains on the slopes of the ancient volcanoes caused the loose ash to flow as mud, bearing large and small blocks of volcanic rocks. Petrified logs and leaves are plentiful in places. Chaney (1956: 47) dates the Eagle Creek flora as Miocene.

The Columbia River Basalt unconformably overlies the Eagle Creek

The first five articles in this issue (by Baldwin, Lynott, Detling, Storm, and Gordon) constituted a Symposium on the Natural History of the Columbia Gorge, presented at the joint meeting of the Northwest Scientific Association and the Oregon Academy of Science held at the Sheraton-Portland Hotel, Portland, Oregon, April, 1965.

Formation and makes up the most striking cliffs and side gorges. It is nearly 2000 feet thick where the base is visible, but it may exceed this farther east where the base is hidden. Only remnants are present high on the north wall of the gorge near Mt. Hamilton, and it probably is missing a short distance to the north of the gorge and also to the south of Mt. Hood. The greater thickness along the Oregon side and the thinning to

Figure 1. Columbia River Gorge. Columbia River Basalt forms cliff at Crown Point in foreground and at Cape Horn by river on north side. Rooster Rock is in left foreground, Mt. Hamilton is cliff on north side of river in the distance and Beacon Rock is by river near Mt. Hamilton. (Photo courtesy of Oregon Highway Commission.)

both north and south where the basalt laps against older rock suggest that the basalt filled a wide valley through the ancestral Cascades. Then the river reexcavated a path along the north side of its former passage.

The Columbia River Basalt is a dense, dark-gray, fine-grained rock with little or no olivine. Vesicular zones are present at the tops of most flows, and in places, such as in Oneonta Gorge, soil formed and trees grew before successive flows poured out. Tree casts are present where the logs were submerged by lava. At Crown Point and near Mitchell Point pillow basalt

indicates that some of the flows were extruded into water, probably lakes formed by disruption of drainage.

Waters (1961) divided the Columbia River Basalt into the lower Picture Gorge Basalt and the upper Yakima Basalt. The basalt in the gorge is more like the Yakima Basalt; the Picture Gorge Basalt may be missing. The age of the basalt is usually given as middle Miocene, because it apparently interfingers with the Astoria Formation which is generally regarded as being of that age. The basalt interfingers with a sandstone member that Dodds (1963) concluded unconformably overlies the middle Miocene part of the Astoria and thus may be late Miocene. The Picture Gorge member underlies the late Miocene Mascall Formation, the age of which is based on vertebrate chronology. Most of the formations overlying the basalt in or near the Columbia River Gorge are continental and lack diagnostic fossils.

The Troutdale Formation, as restricted by Trimble (1963: 26), rests unconformably on the Columbia River Basalt in the gorge and perhaps discomformably upon the Sandy River Mudstone along the west flank of the range. The mudstone was included in the lower part of the Troutdale Formation by previous writers, and it contains the lower Pliocene flora upon which the age of the Troutdale Formation was formerly given. The formation as restricted is made up almost entirely of conglomerate containing a significant percentage of quartzite pebbles derived from far up the Columbia River. Allen (1932) traced the conglomerate through the western part of the gorge, noting its thickening in channels carved in the underlying basalt. Hodge (1938) suggested that the Columbia River formerly swung south and westward through the vicinity of Mt. Hood, with the Hood River a south-flowing tributary, a hypothesis based in part on the distribution of the Troutdale conglomerate. Extrusion of Mt. Hood would have caused the diversion northward. Lowry and Baldwin (1952) found little evidence to support this hypothesis. The presence of Troutdale conglomerate extending through the gorge indicates that the river occupied the same general path as today.

Leaves in the Sandy River Mudstone were considered to be lower Pliocene by Chaney (1942). The Troutdale conglomerate is unconformable upon the mudstone and is perhaps middle Pliocene although it too could be in part lower Pliocene. The Troutdale conglomerate includes the gravels at Hood River and may be equivalent to much of the Dalles Formation east of the gorge.

The Dalles Formation rests on the Columbia River Basalt in the vicinity of The Dalles and laps against the Ortley anticline at the east end of the

gorge. The formation is composed of tuffaceous sandstone and siltstone derived from explosive vents in the nearby Cascade Range. The Dalles Formation is considered to be lower Pliocene on the basis of meager vertebrate remains. Fossil leaves have been dated as Pliocene by Chaney (1956).

The Cascade Andesites, also called the "Cascan" by Hodge (1938), overlies the Troutdale Formation west of Hood River Valley. The formation contains light- to medium-gray, massively jointed, vesicular olivine-bearing andesite (some of it classified as a basalt) usually distinguished from the Columbia River Basalt by the larger blocks, lighter shade and weight, and by its higher stratigraphic position. Flows of this formation crop out in Larch Mountain, Chamberlin Hill east of Troutdale, and in buttes near Gresham, where they have been called Boring Lava. Flows high on the range and along the west flank are probably late Pliocene, but similar intracanyon flows occupying the valleys of Wind, Little White Salmon and White Salmon rivers and the mouth of Herman Creek are Pleistocene, probably late Pleistocene. Underwood Mountain, north of Hood River, is a vent surrounded by Cascade Andesite flows that rest unconformably on the Columbia River Basalt. Some of the younger flows emanated from the vicinity of Mt. Adams and poured down the valleys. Pleistocene to Recent flows are also present in the Hood River Valley at Parkdale.

Pleistocene terrace sands and gravels are present as remnants of former alluvial levels. Recent alluvium borders the river and forms bars and small islands. Coarse flood-strewn boulders lie on terrace deposits but precede deposition of the recent alluvium.

Intrusive rocks are present largely as dikes or swollen portions of dikes, such as Wind-Shellrock Mountains, that fed Cascade Andesite flows. Wind-Shellrock Mountains are a continuous body of porphyritic hypersthene andesite split by superposition of the river. The intrusion penetrates the Columbia River Basalt above and joins the overlying andesite. Beacon Rock is a dike of Cascade Andesite surrounded by Eagle Creek beds.

Structural Geology

The Columbia River Basalt and older formations were folded during the late Miocene and early Pliocene as shown by the onlapping relationship of the Sandy River Mudstone and Troutdale Formation on the west, and the Dalles Formation on the east. The broadest anticline at the west end of the gorge beneath Mt. Hood reaches from the Portland Basin to the Hood River Valley. This is the only part of the gorge uplifted high enough to show the Eagle Creek Formation. A fault lies just east of Wind-Shellrock Mountains

Figure 2. Hood River Valley with fault along west edge of Bingen anticline. The Mosier syncline lies beyond with the Ortley anticline in distance. (Delano Photographics, all rights reserved.)

with the Hood River side downthrown (Figure 2). This fault may be along the western edge of a graben, although it is covered by Cascade Andesite flows and volcanoes such as Mt. Defiance; the eastern margin is more scarplike. The Bingen anticline, the Mosier syncline, and the Ortley anticline lie east of Hood River Valley in that order. The Dalles Basin, which may be considered east of the gorge, lies east of the Ortley anticline. A fault passes through the vicinity of the Rowena loops and trends northeastward along the southeast margin of the Klickitat River Valley and the northwest flank of the Ortley anticline.

Most of the folds mentioned have a northeasterly trend, but the fault along the east edge of the Hood River Valley is north trending and appears to cut across the southern extension of the Bingen anticline. An index map and geologic map of the gorge prepared by J. E. Allen is shown in Baldwin (1964: 62).

Formation of the Gorge

Some question exists as to whether the Columbia River is an antecedent or superimposed stream where it crosses the Cascade Range. There seems to be adequate evidence that a broad valley existed through the range, which filled partially with Columbia River Basalt and then was partially eroded as the river spread the Troutdale conglomerate over a shallow valley. Cascade Andesite flows, which cover the conglomerate along the south edge, may have pushed the river to the northern side of the old valley. Thus the river was there before the range formed and is antecedent. However, during the Plio-Pleistocene, uplift of the broad arch between Portland and Hood River superimposed the Columbia River from the conglomerate and andesite fill upon the Columbia River Basalt and resulted in the gorge we see today. The incision followed extrusion of the Cascade Andesite, which is presumably late Pliocene, and thus the major uplift occurred during the Pleistocene. The gorge is quite narrow where both walls are of Columbia River Basalt but wider where undercutting and mass wastage of the tuffaceous Eagle Creek beds has caused sliding. The gorge was even deeper during the Pleistocene Wisconsin ice advance when the ocean was as much as 450 feet lower than at present, for bedrock is missing in the river west of The Dalles. The rapids at The Dalles was even more spectacular when the base level was lower.

Missoula Flood

The Missoula Flood occurred near the end of the Wisconsin at a time when the ice in the Clark Fork of the Columbia River was retreating. When the ice dam broke, a large volume of water rushed through the channel scablands of eastern Washington only to assemble again at the Wallula Gateway. From there to the sea the level of the flood was governed by constrictions. Icebergs carrying erratics grounded, leaving boulders up to an altitude of 1100 feet at The Dalles, and then the flood crest rather abruptly dropped to 400 feet at the west end of the gorge. Bretz (1925) pointed to spillover channels near the mouth of the John Day River, Fifteenmile Creek, and at Corbett. The principal effect of the flood was to scour loose material such as talus and to veneer existing terrain beyond the gorge with flood debris.

Fryxell (1962) dated organic material in flood gravels near Vantage, Washington, at 32,700± 900 years B.P. Whether this is the same flood that last swept through the gorge is not known. Bretz *et al.* (1956) allowed for more than one flood, but the last flood was the one that had the most effect and tended to mask previous ones.

Landslides

Landslides are major features modifying the slopes of the gorge. A slide at Ruckles, just east of Bonneville Dam, presumably came from the north side and pushed up against the south bank. The material in the slide is largely Eagle Creek Formation and the slide must have occurred prior to the flood, for little remains. Another large slide has pushed the river against the south bank at the Bridge of the Gods and formed rapids in the river. The slide is postflood or it would have been removed. Lawrence and Lawrence (1958) dated logs embedded in the slide as 670± 300 and 700± 200 years B.P.

Rooster Rock appears to be a rootless mass of Columbia River Basalt upended in alluvium. It is lithologically similar to rock in Crown Point, and it evidently slipped out of the cove just west of the point (Figure 1). It is possibly preflood, with surrounding slide material flushed out much in the same manner as tuffaceous Eagle Creek beds were removed from around Beacon Rock. Sliding is continuing as shown by small ponds, tilted trees, power poles and towers, and misalignment of power lines along the slope north of Bonneville Dam.

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Weather and Climate of the Columbia Gorge

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THE COLUMBIA Gorge is a remarkable landform, a low-elevation gateway from west to east through the Cascade Mountain Range of Washington and Oregon. From the standpoint of climate, the gorge provides an unusual transition from a marine-type climate to a continental-type climate. The area on the west side of the Cascades is near the Pacific Ocean, and dominated by maritime air masses. The land area on the east side of the Cascades is sheltered from the oceanic influence by the barrier to the prevailing wind from the west.

Climate is defined as a statistical summary of weather conditions over a fairly long period of time. It is the practice of the U.S. Weather Bureau to establish the so-called normal values of climate, for any given location, upon the averages of 30 years of record.

The word "climate" is derived from the Greek *klima,* meaning inclination, because of the importance attributed to the sun's influence. The angle of the sun, or in other words, the latitude of a given location, is partly responsible for the climate of that location. We speak of tropical climate, or an arctic climate. But many other factors are also important, such as elevation, and the character of the earth's surface, such as water, forest, grass, or desert. With respect to the Columbia Gorge, we are primarily concerned with two basic types of climate, marine and continental.

A marine climate prevails where the atmosphere is under the predominant influence of the sea, that is, high moisture content in at least its lower levels. Such a climate is found where the prevailing winds blow onshore, such as the western coasts of continents in middle latitudes. It extends inland either until it meets a climatic divide, or in level country, until it becomes modified and gradually attains greater continentality. Large bodies of water change temperature very slowly, mainly because of the high specific heat of water. Also, any change of temperature at the surface is spread downward by mixing. Hence, a marine climate is characterized by small daily range of temperature, and a small annual range of temperature. There is a lag in the seasons of about one month in comparison with a continental climate.

A continental climate is characteristic of the interior of a land mass of

continental size. Land surfaces often change temperature rapidly. Changes usually affect only a shallow layer of soil or rock near the surface. The air above is often dry, which favors rapid radiation at night. Hence, a continental climate is marked by a large daily range of temperature, a large annual range of temperature, low relative humidity, and by rainfall that is irregular. The hottest period of the year is soon after the time of highest sun, and the coldest period is soon after the time of lowest sun. In its extreme form, a continental climate produces a desert. Where a mountain barrier lies across the prevailing westerly winds, as in America, the greatest continentality occurs in the lee of the mountains.

Weather, as distinguished from climate, consists of the short-term variations in the atmosphere. We speak of today's weather. Everyone wants to know "what's the weather for tomorrow?"

It is incorrect to visualize the Cascade Mountains merely as a barrier between two relatively stagnant and passive air masses, one described as marine and the other as continental. Air masses are nearly always on the move, assuming one set of characteristics in one area, then moving to another region, and taking on another set of characteristics. Because of hemispheric circulation patterns, the prevailing wind across the Cascades is from the west. Marine air can, and does, move up, over, and across the mountains. In so doing, it expands, cools, and precipitation is encouraged. On the eastern side, the atmosphere blows downhill, is compressed, warmed, and precipitation is inhibited. As a result, annual rainfall statistics show greater differences between the west and east portions of the Columbia Gorge than would obtain if the mountains were not there.

Annual Rainfall at Selected Stations

Vancouver	37.95 inches
Portland, airport	35.23
Cascade Locks	75.60
Headworks, Bull Run	86.41
Hood River Exp. Sta.	30.10
The Dalles	13.80
Arlington	9.07
Umatilla	7.83

It is interesting to note that Cascade Locks has more rain than Vancouver or Portland, and nearly as much as the Bull Run Headworks. The streamlines of westerly winds converge as they blow through the gorge, and much of the air is lifted, with a result similar to that air which blows up the slopes of the Cascades. Cascade Locks has two and one half times as much rain each year as Hood River, which is only 18 miles farther east.

Although the majority of wind movement through the gorge is from west to east, there are many periods when pressure is higher on the east side, and east winds blow through the gorge. Also, there are many times when easterly winds from a depth of a few hundred feet up to a depth of 1000 or 2000 feet have westerly winds above the layer of easterly winds. This is especially frequent in the winter. Such a situation can cause serious weather problems, such as heavy snow, or sleet, or freezing rain.

Freezing rain, or "silver thaw" as it is often called, occurs when ordinary rain falls into a shallow layer of air which is below freezing, and the rain turns to ice after it falls on the ground, or on wires, or on vegetation. If the layer of cold air is somewhat thicker, say 500 to 1000 feet, the raindrops will freeze before impact, and this is called sleet. The Columbia Gorge is famous for its sleet storms, and periods of freezing rain. Such a storm occurred in November, 1921. At The Dalles the accumulation of sleet and snow was to a depth of 54 inches. In the narrow parts of the gorge the heavy accumulations of sleet on the steep slopes resulted in avalanches of sleet which completely covered the highway and railroad to a depth of many feet.

The Columbia Gorge has been described as a giant wind funnel. Although westerly winds can become quite strong, and they are often observed as far east as Pendleton, it is the east winds which are most violent. During the 1930's and early 1940's there was a weather station at Crown Point. The anemometer was of the type that recorded total air movement, and most of the statistics which were compiled were for average hourly wind movement. However, if an observer were present, he could measure the windspeed for periods as short as one minute. During the afternoon of November 23, 1930, Donald C. Cameron observed a peak velocity of 120 mph, and he reported the wind was even stronger during the forenoon before he arrived at the station. On December 20, 1935, all of the wind equipment was blown away, and also part of the roof of the weather station. Peak winds were estimated at 120 mph.

It is true that Crown Point is an exposed promontory, and the wind may be somewhat exaggerated due to a convergence of streamlines, but there is no doubt that many violent winds have been observed in the gorge. When strong winds occur at the time of icy roads, cars and trucks are often blown off the highway. Strong east winds can occur when other weather conditions can be described as "fair," with clear skies and rather mild temperatures. I made a visit to Crown Point during one of those occasions—it was during the fall of 1956, I believe. The wind was blowing about 70 or 80 mph. During a partial lull in the wind I wandered some distance away from my parked car,

then found that I could not stand up and walk back against the wind toward the car; I had to get down on my hands and knees and crawl!

On January 13, 1950, there was a remarkable example of a shallow outpouring of very cold air from the Columbia Gorge into the Portland area, with an over-running of moist marine air from the southwest. The cold air engulfed the weather station at the airport, but the line of demarcation moved very slowly, and for several hours most of the city of Portland was dominated by the warmer air from the Pacific. Here is a quotation from the Oregonian the next morning, after the storm:

> The weather went crazy in Portland Friday. At the airport, the snow kept coming all day, with 8 or 9 inches of white stuff on the ground and drifts to 2½ ft piled up by gusts as high as 45 mph, with the thermometer at 21 degrees. Downtown, pedestrians slopped through rain soaked streets in a temperature of 35 degrees.

I saved a page of airway weather reports from the teletype for that day. At 2:30 p.m. on Friday, January 13, 1950, the following contrasts in weather were reported:

> Salem: Rain, 36 degrees, wind southwest 28 mph
> Portland airport: Snowing, 20 degrees, wind east 26 mph
> Stevenson, Wash.: (in the gorge) Heavy snow, 9 degrees, wind east 49 mph with gusts to 60.

The Flora of the Columbia River Gorge

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A FEW YEARS ago (Detling, 1958) I published a short paper on some of the peculiarities of the Columbia River Gorge flora, in which I included some fairly extensive lists of the plant species commonly occurring there. It is not my wish on this occasion to repeat any considerable part of that paper, but rather, after a brief review of the major features of the vegetation, to consider some of the implications that it holds for the more recent history of the whole Pacific Northwest flora.

From a biological point of view, one of the most notable features of the Columbia Gorge physiography is the fact that it is the only point between the Fraser River in British Columbia and the Klamath and Pit rivers in northern California where the Cascade axis has been cut through to the point where it interrupts the continuity of all the life zones except the lowest. The significance of this fact lies in the role the gorge has played in the migrations of plant species from one side of the range to the other.

The valley floor and lower slopes at the west end of the gap are occupied by a mesic conifer forest consisting largely of Douglas-fir and big-leaf maple, with a dense understory of vine maple, hazel, red huckleberry, salal, and low Oregon grape. With certain exceptions to be noted later, this is the basic type of vegetation on the cool, north-facing slopes of the gorge, extending clear to the east portal. The lower elevations beyond the east end of the gorge are covered with a yellow pine forest or grassland. Representative of this phase are:

Castilleja hispida
Ceanothus velutinus
Eriogonum sphaerocephalum
Helianthus cusickii
Iliamna rivularis
Lewisia rediviva
Penstemon subserratus
Pinus ponderosa
Philadelphus lewisii lewisii
Trifolium macrocephalum

This more xeric type tends to follow through the gorge along the warm, dry, south slopes of the Washington side, some of the species ranging as far westward as Cape Horn.

Another floristic feature of interest is the fact that a considerable area near the bottom of the gorge constitutes an island, or perhaps several islands, of boreal flora. The cool, moist conditions that obtain through the summer

months in the lateral canyons, particularly in the mist around the waterfalls, are apparently what has made it possible for these species to persist here, isolated from the nearest boreal flora above them by at least 4000 feet of mesic forest. You will recognize the following few species of typical members of the Canadian or Hudsonian Zones in the Cascades:

Acer glabrum douglasii
Alnus sinuata
Cornus canadensis
Dodecatheon dentatum
Haplopappus hallii
Penstemon rupicola
Saxifraga bronchialis vespertina

A group of about 10 boreal species, including three of the foregoing, have a peculiar distribution today, in that they occur in the gorge, on the Saddle Mt. boreal island in Clatsop County, and in the Olympic Mountains, but have not been reported from the low or middle elevations between these points. The group is comprised of:

Acer glabrum douglasii
Alnus sinuata
Antennaria racemosa
Campanula petiolata
Lomatium angustatum
Phlox diffusa longistylis
Polypodium vulgare columbianum
Saxifraga bronchialis vespertina
Saxifraga caespitosa
Stenanthium occidentale

Still another group of species closely allied ecologically to the preceding are endemic to the Columbia Gorge or its immediate vicinity. The best known of these are:

Bolandra oregana
Douglasia laevigata laevigata
Erigeron howellii
Erigeron oreganus
Hieracium longiberbe
Sullivantia oregana
Synthyris stellata

Of this group the species of *Bolandra* and *Sullivantia* are noteworthy for their occurrence on Elk Rock on the Willamette River, near Oregon City. The distribution of these two gorge species, as well as those occurring on Saddle Mt. and the Olympic Mountains, points to a former occupation of low elevations by the boreal flora represented in the gorge.

Relict occurrences of any floral type can usually be ascribed to changing climates, in the course of which a flora has been forced to retreat, leaving behind small populations in restricted areas of suitable conditions. In the case of the boreal species at the bottom of the gorge, it is not inconceivable that they should have been transported there from the slopes high above their present niches, even though, to my knowledge, they do not occur at intermediate levels. But this would not account for their presence in the more distant boreal islands.

I like to speculate on the timing of any vegetational shifts and migrations

for which we have evidence, largely because of the light such speculation may shed on the rate of evolution. This is sometimes difficult because, as in the case of geological history, later events frequently confuse or obliterate the results of earlier ones.

The only period during which the boreal island or islands in the Columbia Gorge could have been formed was that of the Pleistocene Ice Age. Paleobotanical as well as other evidence indicates that the Pacific Northwest had a temperate climate from the Oligocene through the Pliocene. At no time during that period was the climate severe enough to cause the downward, or southward, migration of a boreal flora into the bottom of the Columbia Gorge. Throughout the Tertiary, however, there was a gradual decrease in mean temperatures, which reached its culmination in the Ice Ages of the Pleistocene. But since the retreat of the last ice sheet this region has again had a temperate climate.

Students of Pleistocene glaciology have shown that during this epoch there was not just one southward advance of an ice sheet, but apparently four, and that these advances were separated from one another by three relatively warm periods when average temperatures were sometimes higher than they are even at the present time. This being so, we must suppose that south of the glaciers in the Pacific Northwest the cold maxima alternated with long periods of warmer climate during which the boreal flora would take refuge in the higher elevations and in more northern latitudes. We suppose that during the glacial recessions some of the boreal species were left in relict islands. During subsequent cold phases of the climatic cycle the islands would be eliminated as such by the spread of the boreal flora over the lowlands, and their loci might or might not be repopulated with the same species as before, and with the next retreat the original relict species might or might not persist. The result is we do not know for certain which glacial advance brought the species of a given present-day island into place. And it is even probable that the present islands are not all of the same age.

The boreal phases of the Columbia Gorge and Saddle Mt. floras, with their relatively large numbers of constituent species, would appear to have originated fairly late in the Pleistocene. Just how late must be determined by a study of individual species. *Saxifraga bronchialis* may serve as an example. Subspecies *bronchialis* occurs in Siberia, while several subspecies have evolved in North America. Ssp. *austromontana* ranges from southern British Columbia and Alberta south through the Rocky and Blue mountains, and in the Cascades to southern Washington. Ssp. *vespertina* ranges from the Columbia Gorge southward in the Cascades to Lane County, and occurs on Saddle Mt. and in

the Olympics. Apparently divergent evolution took place in the Cascade axis after *austromontana* was well established in both the Rockies and Cascades. *Vespertina* was a later offshoot but was well enough established at least by the last or Wisconsin advance to have populated the lowlands between the gorge and Saddle Mt. and the Olympics.

More recent evolutionary change is probably shown in such species as *Arnica amplexicaulis* and *Haplopappus hallii,* whose gorge populations differ slightly from the main populations, but still not to the extent where the taxonomic specialists in these genera are willing to grant the gorge plants even varietal status.

An entirely different phase of the Northwest flora is represented in the Columbia Gorge by a considerable number of species of southern origin, xeric in their ecological requirements, and which arrived here during a warm-dry maximum of the climatic cycle. A representative list of such species would include first of all the Oregon white oak (or Garry oak), and such associated species as:

Balsamorhiza deltoidea
Brodiaea grandiflora howellii
Brodiaea pulchella
Eriogonum compositum pilicaule
Leptotaenia dissecta
Lupinus bicolor
Senecio harfordii
Viburnum ellipticum

This association is common in the Rogue River Basin and occurs more or less sporadically west of the Cascades as far north as southwestern British Columbia, some of the species being found only in very restricted xeric islands. The only place the association occurs east of the mountains is in an area at the head of the Columbia Gorge extending from Yakima County to southern Wasco County. The peak of the xero-thermic phase mentioned above apparently occurred about 6500 years ago (Hansen, 1955). In a previous publication (Detling, 1961) I postulated a mean summer temperature at that time 5°C (9°F) above the present summer mean, and a mean annual rainfall 230 mm (9 in.) less than the present. By that time the Rogue River flora, consisting largely of a chaparral formation, had migrated northward to Puget Sound, while certain elements of it migrated eastward through the Columbia Gorge and spread out into the region at the head of the gorge. During this migration the xeric flora undoubtedly restricted but did not obliterate the boreal flora in the gorge, and may have spread largely by way of the south slopes on the Washington side of the river.

As the climate became cooler and wetter in the Northwest the Rogue chaparral retreated, leaving remnants of its associates in the Columbia Gorge and the other more or less restricted areas where we find them today.

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Amphibians and Reptiles

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IN CONSIDERING the effect of the Columbia River on amphibians and reptiles, several general patterns can be pointed out. The first of these is a pattern of no apparent barrier effect by the river. Some 14 amphibian and 15 reptile species show a present-day distribution on both sides of the Columbia. Twelve of these are part of a northwestern or Oregonian fauna and occur largely west of the Cascades (*Dicamptodon ensatus, Rhyacotriton olympicus, Ambystoma gracile, Ambystoma macrodactylum, Taricha granulosa, Plethodon vehiculum, Ensatina eschscholtzi, Ascaphus truei, Rana aurora, Rana cascadae, Gerrhonotus coeruleus,* and *Thamnophis ordinoides*). Two would seem to be part of a California fauna, extending into Oregon from the south (*Clemmys marmorata* and *Gerrhonotus multicarinatus*). Seven belong to a desert fauna, and these have probably crossed into central Washington from the south or southeast (*Scaphiopus hammondi, Sceloporus graciosus, Phrynosoma douglassi, Eumeces skiltonianus, Thamnophis elegans, Pituophis catenifer,* and *Hypsiglena torquata*). Of the remaining eight species, four are members of a widespread Austral fauna (*Sceloporus occidentalis, Thamnophis sirtalis, Coluber constrictor,* and *Crotalus viridis*), three are Cordilleran in their affinities (*Bufo boreas, Rana pretiosa,* and *Charina bottae*), and one is difficult to categorize (*Hyla regilla*).

Pattern two exhibits a partial barrier effect by the river and involves one amphibian and seven reptiles. The amphibian, *Plethodon dunni,* occurs through western Oregon is suitable habitat, but occurs only in extreme southwestern Washington. *Clemmys marmorata* and three snakes, *Diadophis amabilis, Contia tenuis,* and *Lampropeltis zonata,* are spottily recorded in Washington. In eastern Washington, *Masticophis taeniatus* and *Uta stansburiana* are not widely distributed west of the Columbia. One species of snake, *Thamnophis sirtalis,* is almost divided into the subspecies *concinnus* and *trilineata* by the Columbia, but *concinnus* crosses into the extreme southern part of western Washington.

In the third category are those few forms to which the Columbia apparently has been a complete barrier. These include *Plethodon vandykei* of western Washington, *Batrachoseps wrighti* of the west flank of the Oregon Cascades,

and *Aneides ferreus,* which although absent from western Washington, reappears on Vancouver Island. The leopard lizard, *Crotaphytus wislizeni,* occurs at one or two localities on the south bank of the Columbia in eastern Oregon, but these seem to be relict locations and are perhaps not good examples of a barrier effect.

The evidence is overwhelmingly against the effectiveness of the Columbia River as a barrier, at least as we examine present-day ranges. Of 41 species of amphibians and reptiles, only two actually seem to be stopped by this river and a possible seven forms are partially blocked.

In attempting to explain this phenomenon, one can speculate as follows:

1. For considerable lengths of time, probably since the Pliocene, the Columbia has not presented the barrier that it now does. One possibility exists in the xeric high of several thousand years ago, although one feels that whereas this may have enabled reptiles to cross the river, it would have driven amphibians into moist refugia, thus limiting their movements.

2. Some reptiles, particularly snakes, may be able to cross the river often enough to have become established. In fact, we may greatly underestimate the swimming abilities of adult amphibians or their larvae.

3. A more thorough knowledge of the variations of populations on both sides of the river might turn up as yet undiscovered genetic divergence, for which the river barrier is responsible. In this regard, however, careful studies by Robert Stebbins on the salamanders *Rhyacotriton* and *Ensatina* and by Ferguson on *Ambystoma macrodactylum* have not borne this out.

If we now turn to a consideration of the effect of the Columbia Gorge itself, two further patterns can be explored. The first of these involves the expected possibility that certain aquatic or semi-aquatic reptiles might well have been carried steadily westward, in a distributional sense, by the generally westward flow of the river. In actuality, one species, *Chrysemys picta,* fits this category, having been carried at least to the Willamette River in which it has moved southward as far as Corvallis. Two amphibians, *Bufo woodhousei* and *Rana pipiens,* have not reached the gorge, but have obviously been carried almost to it by the river.

If one considers all the other amphibians and reptiles of eastern Oregon and Washington that might well have utilized this low elevation passage to western Oregon (a possible total of about 12), there is no clear-cut evidence that any of them have even begun the trip on the Oregon side, and none has apparently made it through on the Washington side.

Finally, as a last pattern, what have the western Oregon and Washington forms done about this low road through the mountains? At least two, *Ger-*

rhonotus multicarinatus and *Diadophis amabilis,* appear to have used it to extend their range into small areas east of the mountains. In Oregon, the alligator lizard ranges as far south as the Deschutes Canyon near Redmond. Living specimens from this Deschutes population are distinctly lighter in color than those from western Oregon, but are apparently identical in details of scalation.

Two amphibians may have made the eastward trip through the gorge. These are *Dicamptodon ensatus* and *Taricha granulosa,* both of which occur at Oak Springs, near Maupin, in the Deschutes Canyon. It is, however, noteworthy that both of these animals occur in northern Idaho and western Montana. Several typically western Oregon forms extend surprisingly far eastward on the Oregon side of the gorge, getting at least to Starvation Creek (about 10 miles west of Hood River). These include six salamanders (*Dicamptodon ensatus, Rhyacotriton olympicus, Plethodon dunni, Plethodon larselli, Batrachoseps wrighti,* and *Ensatina eschscholtzi*), and one each of a frog (*Ascaphus truei*), a lizard (*Gerrhonotus coeruleus*), and a snake (*Thamnophis ordinoides*). Finally, there is some evidence for a greater use of the gorge as a passage from west to east and possibly vice versa. This is one interpretation of the following example. Gopher snakes of extreme southeast Oregon (subspecies *deserticola*) differ from those of central western Oregon (subspecies *catenifer*) in seven characters. If gopher snake specimens from all parts of Oregon are analyzed as to whether each of these characters is either *deserticola*

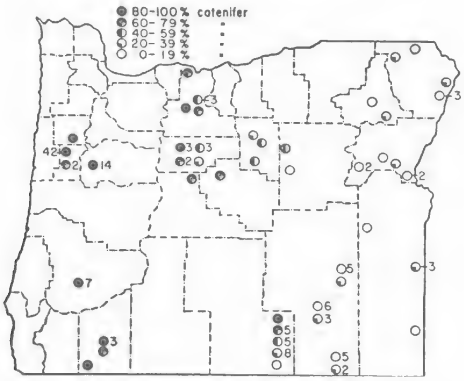

Figure 1. Intergradation between *Pituophis catenifer catenifer* and *P. c. deserticola* in Oregon.

or *catenifer,* one gets the results seen in Figure 1. Granting the several gaps in the figure, there appears to be an infusion of *catenifer* characters through the gorge and into north-central Oregon.

Summary

1. The Columbia River is not an effective barrier in the light of present-day amphibian and reptile distributions. Of 41 species, only nine demonstrate at least some barrier effect by the river. The reasons for this pattern can only be speculated upon.

2. One reptile species has extended its range to western Oregon and Washington by way of the gorge, and two eastern anurans have westward range extensions along the Columbia east of the Cascades.

3. Two reptilian species have reached eastern Oregon and Washington by way of the gorge, but although several amphibians range far eastward in the gorge itself, they apparently do so by virtue of a most climatic regime, similar to that west of the Cascades.

4. Among species occurring both east and west of the Cascades, gene interchange may occur through the gorge.

Mammals and the Influence of the Columbia River Gorge on Their Distribution

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THIS PAPER deals with the Columbia River to the confluence of the Snake River and the latter stream to the point where it flows around the north end of the Blue Mountains, and considers these streams as they were before various dams were built. The influence of the gorge cannot be treated apart from the effect of the entire river system from the Blue Mountains to the ocean.

One would expect in the first place that the Columbia River would be a barrier for a considerable number of mammals; and in the second place that the gorge would let many mammals breach the Cascade barrier that could not go over an unbroken range.

The mammals that reach the vicinity of the Columbia River can be assigned to a number of different groups according to their distribution in relation to Oregon. Common names are taken from Burt and Grossenheider (1964). Bats are omitted.

A wide-ranging North American group extends over most of North America, but is better represented in the northern parts. Fourteen members are found in the vicinity of the Columbia River, and all have transgressed the stream. They are coyote, gray wolf, black bear, longtail weasel, mink, river otter, mountain lion, least chipmunk, beaver, deer mouse, muskrat, porcupine, elk, and whitetail deer.

A wide-ranging boreal forest group is characteristic of the coniferous forest of Canada and Alaska and ranges down the Cascade-Sierra chain and the Rocky Mountains, and is especially prevalent in the subalpine forest. Ten members are found on both sides of the Columbia River: northern water shrew, northern flying squirrel, mountain phenacomys, snowshoe hare, red fox, marten, fisher, shorttail weasel, wolverine, and lynx.

There are several wide-ranging Austral mammals that are found over most of the United States, northern Mexico, and southern Canada. Four of these are found on both sides of the river: raccoon, striped and spotted skunks, and bobcat. The gray fox has not crossed to the north bank.

A cordilleran group extends from a common base in southwestern Canada

down the Cascade-Sierra and Rocky Mountain chains, but ranges down to somewhat lower elevations than the boreal assemblage usually does. Fourteen of these are found on both sides of the river: vagrant shrew, grizzly bear, yellow pine chipmunk, yellowbelly marmot, golden-mantled ground squirrel, northern pocket gopher, bushytail woodrat, longtail vole, mountain vole, Richardson vole, western jumping mouse, pika, mule deer, and bighorn sheep. The hoary marmot does not quite reach the river from the north.

An Oregonian division is characteristic of the dense, humid forest of the northwest coast, and centers in western Oregon. Twelve are found in western Oregon and Washington: Pacific water shrew, shrew-mole, Pacific mole, Townsend mole, Aplodontia, Townsend chipmunk, chickaree, Mazama pocket gopher, California redback vole, Townsend vole, Oregon vole, and Pacific jumping mouse. Three occur only south of the Columbia River: giant pocket gopher, tree phenacomys (P. longicaudus + silvicola), and Pacific phenacomys.

The deserts, grasslands, and sagebrush areas are the typical habitats of a large group of mammals. Many enter Oregon from the Great Basin in Nevada. Fourteen of these extend down the Deschutes: Merriam shrew, badger, Townsend ground squirrel, Great Basin pocket mouse, Ord kangaroo rat, northern grasshopper mouse, western harvest mouse, sagebrush vole, pronghorn, bison, whitetail jackrabbit, blacktail jackrabbit, mountain cottontail, and pygmy rabbit. A more localized species, the Washington ground squirrel, has crossed the Snake River but not the Columbia River.

A small number of a California division, usually found in chaparral or brushy areas and in oak woodlands, enter southwestern Oregon. Two, the brush rabbit and the dusky-footed woodrat, have reached but not crossed the river. Two, the western gray squirrel and California ground squirrel, have crossed into Washington.

Thus, of 80 species found at or near the Columbia River, 68 are found on both sides, 12 are found on one side only. Of these 12, nine are of mainly southern distribution (5 are in the Oregonian and Californian groups).

Eight species have been stopped by the river below the gorge, and four have been stopped in, or in and below, the gorge.

Of the 68 that are found on both sides 52 have the same subspecies on opposite sides, 3 have different subspecies, 12 have partly the same, partly different subspecies in different parts of the river's course. Of 106 subspecies found in the species that transgress the river, 83 are found on both sides, and 23 on one side only.

The difference is even greater for amphibians and reptiles, where about 42 species are found on both sides, and only 2 on one side. The number of

subspecies common to the two sides is proportionately much larger than in mammals.

Thus it is apparent that the Columbia River is not as much of a barrier for species or even subspecies as we might expect. The question, then, becomes one of why the river is not more effective as a barrier in separating species, and in stopping gene flow between separated populations and allowing a greater number of distinct subspecies to develop on opposite sides of the river. A number of hypotheses may be postulated to explain how animals could be transferred from one bank to the other, and thus maintain some gene flow.

Swimming. Some animals might swim the river. But the river is broad and the current strong through and below the gorge. It is hard to imagine that very many of the small mammals and herps could make it across. The chances might be somewhat better above the gorge, especially during the slack flow of summer.

Rafting. This is an unlikely means. "Rafts" would consist mainly of logs and single trees, not large masses of tangled vegetation and soil; and they would be common only during flood times. They would offer little stable foothold where an animal could cling long enough to be stranded on the opposite shore.

Ice bridges. Even now the river above Portland occasionally freezes over, and in cooler glacial and postglacial times this must have happened more frequently. Larger animals might cross occasionally, but the smaller ones would rarely venture out on broad expanses of ice. Hibernating animals would, of course, have no chance to use such a bridge.

Shifting channels. Unlike rivers in flatter lands, such as the Missouri River, the Columbia River does not often change its channel so as to transfer whole sections of real estate and their inhabitants from one side of the main stream to the other.

Our knowledge of the primitive conditions of the river and of the dispersive ability of the animals is unfortunately limited. But from what we do know it is hard to understand why the river has had so little effect as a barrier.

Perhaps we can find in the past history of the area, especially in that of the last or Wisconsin glacial stage, some hint to the answer. The western edge of the coalescent cordilleran ice sheet extended across Vancouver Island and the Strait of Juan de Fuca, then southward down the Puget Sound lowland, down the Cascade Mountains to Mt. Adams, and east across northern Washington and Idaho, blocking the course of the Columbia River a little below Grand Coulee (Flint, 1957).

Climatic and vegetation belts were greatly depressed. Pollen studies by

Hansen (1947) reveal no trace of a tundra belt next to the ice front. The characteristic pioneer trees on deglaciated areas west of the Cascades were lodgepole pine and white pine, followed by Douglas-fir and western hemlock. East of the Cascades the succession was lodgepole pine and white pine, yellow pine, and chenopods and composites in drier areas. From higher elevations in the Cascades there are indications of a subalpine forest of white pine, white-bark pine, Engelmann spruce, white and alpine firs, and mountain hemlock. It would seem, then, that the main vegetation types had much the same positional relationships to each other that they have today, but that the higher belts were forced downward, and that all belts were compressed in area.

If this is correct, we can infer that with the advance of the ice animals moved downward and southward, but need not have been forced south of the Columbia River except for such groups as the wide-ranging arid land and the Great Basin groups that were adapted to a warmer and drier climate. At the height of glaciation these groups might well have retired into Oregon, or in part into Nevada. Wide-ranging North American, wide-ranging boreal, cordilleran, and Oregonian groups could have in large part persisted north of the Columbia River. (See Dalquest (1948) for a long and interesting speculation on the glacial and postglacial history of the mammals of Washington.)

Such statements are based on the postulate that a pattern of distribution very similar to the present pattern had been established before the advance of the Wisconsin ice, and that the advance of the ice simply compressed the pattern in its northern parts, and left the way open for its reestablishment as the ice retreated. They beg the question of how the pattern was formed in the first place. And they give no answer to the question of why so many subspecies are the same on both sides of the river. Perhaps if careful studies were made in the light of modern ideas of population genetics, gene pools, and gene flow of populations on both sides of the river they would reveal that there is more subspecific differentiation than we now consider to be the case.

The gorge has been a highway whereby a few mammals have breached the barrier of the Cascades. Two Californian forms have moved east through it, the western gray squirrel and the California ground squirrel, and then spread north and south in the yellow pine forest. The mountain vole, muskrat, and whitetail deer have moved west into western Washington and Oregon. There is a marked gradient of climate, soil type, and vegetation through the gorge, and apparently few mammals can adjust to the radically different ecological conditions at the opposite ends.

In short, we can raise far more questions than we can answer, and we face the situation where we need to know much more about the taxonomy and dis-

tribution of the species that reach or approach the river, about their rates of evolution, about their dispersive abilities, about the geological history of the region, about the effects of glaciation on climate and vegetation, and about the prior patterns of distribution that were affected by these changes.

No river system in North America offers better opportunities for the study of the barrier influence of a river than the Snake River from its source in Yellowstone Park to its confluence with the Columbia River and that stream from this point to the ocean.

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The Annual Production of the Whitefishes Coregonus clupeaformis and C. nasus in Teslin Lake, British Columbia

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COMMERCIAL FISHING in many northern lakes has been regarded as a marginal venture because of the limited biological production caused by a short growing season and a large body of cold water in the hypolimnion. Lake Teslin is such a lake. In 1944 the Fisheries Department of British Columbia provided funds for a limnological study of the lake. A preliminary report was published in 1945 (Clemens, Boughton, and Rattenbury), but much of the data and biological collections remained intact and unused.

In 1944 Teslin Lake was one of the few large remaining lakes in British Columbia that still existed under almost natural conditions. Except for the personal requirements of a few local residents, no exploitation had been made of its fisheries resources; consequently, the data and biological collections made at that time now become very important in attempting to calculate the commercial whitefish production of the lake.

Lake Teslin lies across the British Columbia-Yukon boundary line. It is 78 miles long, averages 2 miles wide, and is situated at an elevation of 2270 feet. The drainage area, which forms part of the Yukon River drainage system, is extensive and in excess of 11,000 square miles. It consists of gently sloping hills and mountains partly covered by small trees, with pockets of denser growth at the lower levels. The average depth of the lake is 194 feet, and the maximum depth is 702 feet. The total bottom area of the lake is 138 square miles, and the volume in cubic feet is 7346×10^8. The maximum surface temperature recorded during the summer of 1944 was 19.1°C, and the minimum bottom temperature was 3.99°C. The oxygen content of the water was determined by the Winkler method, and in only one instance was the saturation below 80 per cent. The hydrogen-ion concentration ranged from 7.9 to 8.1 at the surface to 7.6 and 7.5 at 275 and 300 feet, respectively. Therefore, the pH range recorded conforms to that of most open lakes.

Teslin Lake supports eleven species of fish. Of these *Coregonus clupeaformis* (Mitchell), the lake whitefish, *C. nasus* (Pallus), the broad whitefish, *Prosopium cylindraceum* (Pallus), the round whitefish, and *Catostomus catostomus* (Forster), the longnose sucker, are bottom feeders. The calculation of the annual yield, however, has been restricted to that for the two species *Coregonus clupeaformis* and *C. nasus* for two obvious reasons: first, because they are of commercial importance owing to their sizes and numbers, and second, because they feed on bottom organisms for which quantitative data have been secured.

Bottom Organisms

A study was made on the quantity of bottom organisms available as food for fish. Eighty-four bottom samples were taken with a nine-inch Ekman dredge. For the most part, dredgings were taken in series from near shore line outward; on occasion they were extended across the lake. Samples were taken to a depth of 375 feet. In the shallow areas inorganic matter consisted largely of stones, sand, and silt, with the silt content increasing progressively with depth. After sifting the material through two screens of different mesh sizes, the organisms were picked off the screens, preserved in 10 per cent formalin, and later counted and weighed. The molluscs were weighed after the shells were removed.

The dominant organisms were midge larvae and pupae, oligochaete worms and molluscs (Table 1). Other miscellaneous organisms were: *Hydra,* Nematoda, Hirudinea, Bryozoa statoblasts, Gastropoda egg masses, *Hyalella,* Ephemeroptera nymphs, Trichoptera larvae, Coleoptera larvae, Tipulidae larvae, Hydracarina, and plant materials. The absence of such bottom organisms as *Pontoporeia, Mysis,* and burrowing mayfly nymphs is noteworthy.

Both molluscs and nonmolluscs in the different depth zones show good correlation between mean weight times mean numbers. This would indicate that either is a good measure of the amount of bottom fauna, and that there is no "dwarfing" of bottom organisms in the greater depths.

An examination of the dredging data provided in Table 1 brings out clearly the occurrence of relatively high productive zones in shallow (0-35 feet) and deep water (90+ feet). Between these zones there is a region which is relatively unproductive. This condition resembles that in Lake Nipigon, where the number of organisms is highest in both shallow and deep water and lowest in the intermediate depths (Adamstone, 1924). Rawson (1953) found a somewhat similar deepwater increase in benthos existed in Great Slave Lake, but this was of much less magnitude and occurred approximately between the 350- and 450-feet depths.

TABLE 1.

SUMMARY OF DREDGING DATA FROM TESLIN LAKE (All figures are based on a dredge area of 81 square inches)

Depth in ft.	*No. of samples*	*Non-Mollusca*					*Mollusca*		*Total*	*Total*
		Average no. midges	*Average no. oligochaetes*	*Average no.misc.*	*Total av. no.*	*Wet wt. in gm.*	*Average number*	*Wet wt. less shell*	*av. no. organisms*	*wet wt. in gm.*
0- 15	28	28.18	14.07	2.07	44.32	0.0732	14.54	0.0349	58.86	0.1081
15- 35	15	19.00	17.47	0.40	36.87	0.0678	13.87	0.0349	50.74	0.1027
35- 50	9	6.77	11.55	0.78	19.11	0.0414	5.11	0.0110	24.22	0.0524
50- 90	13	3.46	1.38	0.69	5.54	0.0154	5.58	0.0118	10.92	0.0272
90-160	11	6.36	10.36	1.00	17.73	0.0402	3.55	0.0145	21.46	0.0547
160-	8	10.38	9.88	0.38	20.63	0.0349	2.38	0.0008	23.01	0.0357
Totals	84	74.15	64.71	5.32	144.20	0.2729	44.83	1.079	189.21	0.3808
Means of all dredgings		15.868	11.558	1.119		.0519	9.395	.0228	37.967	.0748
Mean depth zones given equal weight		12.358	10.785	0.887		.0455	7.472	.0180	31.535	.0635
Total organisms		3189								
Total weight		6.2798 gr.								

When the standing crop of bottom organisms in Teslin Lake is compared with that in other lakes in Canada, the number of organisms per square yard appears to be less than the average for such lakes as Slave, Athabasca, Reindeer, and Nipigon, but larger than in Lakes La Ronge and Wollaston, and much larger than that of Cree Lake. It also appears that Teslin Lake has fewer species than have most of the above-mentioned lakes.

Food Organisms

Table 2 summarizes the stomach contents of 50 specimens of *Coregonus clupeaformis* and *C. nasus* combined. Food data for the separate species are not available because the separation of the two species systematically was made well on in the investigation. Comparison of the abundance of bottom organisms with the food of the two species of whitefish indicated that the dominant food organisms were generally the same as the dominant bottom organisms. It is assumed, therefore, that bottom organisms can be utilized to establish for the two species a tentative annual quota that might be removed from Teslin Lake each year, without seriously depleting the population.

TABLE 2.
STOMACH CONTENTS OF 50 WHITEFISH
Coregonus clupeaformis AND *C. nasus* FROM TESLIN LAKE

No. of fish	*Type of food*	*Average quantity in per cent*	*Range in per cent among individuals*
39	Sphaeridae	31.4	0- 85
37	Gastropoda	56.4	0-100
36	Midge larvae	29.6	0- 98
20	Midge pupae	10.2	0- 50
17	Hydracarina	5.0	0- 80
8	Plant material	7.0	0- 50
6	Ostracoda	3.0	0- 10
4	*Gammarus*	16.0	0- 30
4	Oligochaeta	1.0	0- 1
3	Trichoptera larvae	31.0	0- 90
3	Cladocera	34.0	0-100
3	Statoblasts	trace	
2	Misc. Diptera	trace	
2	Bryozoa	65.0	40- 90
2	Coleoptera	trace	
1	Copepoda	100.0	
1	Formicidae	trace	
1	Water Boatman (2)	95.0	
1	*Gordius*	2.0	
1	Trichoptera pupa	1.0	

Commercial Fish Production

Very few investigations have been carried out that would enable one to forecast, with any degree of accuracy, the yearly yield of fish from a lake. The authors, however, have attempted to calculate a potential annual yield for Teslin Lake, so that the figure might be employed as a starting point in an experimental program aimed at establishing a practical yearly quota for the two species of fish. It is realized, of course, that the final figure derived is a tentative one; for any degree of accuracy, many more data, including many weekly and monthly records such as those suggested by Ricker (1946), would be required.

In determining the annual whitefish production for *Coregonus clupeaformis* and *C. nasus* from a short-term investigation of a lake such as Teslin, several assumptions have been made:

1. The "standing crop" of bottom organisms represents the weight of the food organisms present at any one time. At present, there is no way of determining what percentage of bottom organisms the fish have consumed during a year, and an arbitrary figure of 50 per cent has been chosen. That is, if the standing crop of bottom organisms is 700,000 pounds at any given time, then it is assumed that the fish have consumed 700,000 pounds during the previous year, for body maintenance, growth, and movement.

2. Statistically, it is difficult to determine a conversion factor for the transformation of wet weight of bottom organisms, as shown in Table 3, to that of wet weight of fish. Some of the difficulties involved in the study of the metabolism of fishes are indicated by Winberg (1960). Experiments in the laboratory, under ideal conditions and with a high protein diet, indicate that a conversion factor as high as 2:1 may be attained, but in the natural habitat the conversion is certainly much lower, due to the composition of the food. In comparison with prepared foods, bottom organisms would be low in calories and high in roughage. Rawson (1959) suggested a conversion factor of 10:1, and this figure has been used in calculating the annual whitefish yield for Teslin Lake. On this basis, 10 pounds of bottom organisms would produce 1 pound of whitefish.

3. Since the dredge was operated to a depth of 375 feet, the area of the bottom to a depth of 400 feet has been calculated, namely, 120 square miles out of a total bottom area of 137 square miles. The weight of bottom organisms on 120 square miles has been calculated as the amount of food available to the bottom-feeding fishes in Teslin Lake. The various bottom areas are shown in Table 3.

4. With only *Coregonus clupeaformis* and *C. nasus* under consideration for commercial exploitation, it was necessary to eliminate from consideration the round whitefish, *Prosopium cylindraceum,* and the longnose sucker, *Catostomus catostomus,* in determining the annual yield of whitefish under discussion. On the basis of gill-net records, *C. clupeaformis* and *C. nasus* constituted 3.4 out of a total of 4.4 by weight for all bottom-feeding fish.

With these assumptions in mind, the calculation of the potential produc-

tion of the two species of whitefish was derived. The 120 square miles of bottom was divided into six convenient areas based on the data in Table 3; knowing the average wet weight of bottom organisms for each area, the total bottom-feeding fish population per acre was determined. Then, using the ratio 3.4:4.4, the longnose sucker and the round whitefish were eliminated from the production figures. This last figure represented the yearly potential yield of *C. clupeaformis* and *C. nasus.* The totals for the six areas, when added together, suggest a yearly potential of 63,631 pounds (Table 3). The calculation, showing the method for determining the productivity of one bottom area, is as follows:

Area: 0-15 feet: 27 square miles

Average weight of bottom organisms per square feet =

$$.1081 \text{ (Table 1)} \times \frac{144}{81} = .1922 \text{ gm.}$$

No. of pounds of bottom organisms per acre =

$$\frac{43950 \times .1922}{454} = 18.56 \text{ lb.}$$

No. of pounds of bottom fish per acre =

$$\frac{18.56}{10} = 1.856$$

No. of pounds of commercial whitefish per acre (after removing the longnose sucker and round whitefish) =

$$\frac{3.4}{4.4} \times 1.856 = 1.44$$

Total annual production of commercial whitefish for this one bottom area =

$$27 \times 640 \times 1.44 = 24{,}883$$

Reserving 10,000 to 15,000 for the local population, it would appear that 40,000 to 50,000 pounds might be taken from the lake annually in a commercial fishery.

The calculated weighted, average commercial whitefish production for Teslin Lake is 0.8 pound per acre. This figure appears to be in line with those suggested for other Canadian lakes by Rawson (1947, 1953, 1959). However, direct comparisons between the calculated production in Teslin Lake with production figures in other lakes is not possible, because the figures provided are primarily based on commercial catch records, and frequently all commercial species, whereas the authors' figures are for the two commercial whitefishes, and the annual yield is based on the weight of bottom organisms available as food. Withler (1955), for example, suggested a commercial fish quota for Atlin Lake or one pound per acre or approximately 150,000 pounds annually, but does not specify the species that he considers to be of commercial value. On the basis of lake area, and possibly several species of fish, Withler's quota for Atlin Lake approximates the figure calculated for Teslin Lake.

TABLE 3.

COMMERCIAL WHITEFISH PRODUCTIVITY OF TESLIN LAKE

Depth range in ft.	*Bottom area sq. mi.*	*Bottom area acres*	*Av. wet wt. bottom org.*	*Lb. bottom fish per acre*	*Lb. comm. whitefish per acre (wet wt.)*	*Annual comm. whitefish production (wet wt. lb.)*
0-15	27	17,280	.1922	1.86	1.43	24,883
15-35	13	8,320	.1826	1.77	1.37	11,398
35-50	6	3,840	.0930	.90	.70	2,688
50-90	14	8,960	.0484	.47	.34	3,073
90-160	18	11,520	.0972	.94	.73	8,364
160-400	42	26,880	.0635	.64	.49	13,225
Total	120	75,520	.109			63,631

If Teslin Lake is ever opened up for commercial fishing, the authors suggest that it be kept under direct scientific control. Accurate catch records, length and weight measurements, scale samples for age determination, and other data on the different species of fish taken would be required to maintain a commercial fishery on a sound basis.

Acknowledgments

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Effect of Charcoal on Germination of Douglas-fir Seed

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CHARCOAL IS deposited on the ground whenever fire occurs in a forest. Whether charcoal represents a seedbed that is favorable or adverse to seedling establishment, however, is not well known. The principal reason for differing views on this subject appears to be failure to separate effects of charcoal from other effects of fire on germination and growth of seedlings. Such other effects might be temporary elimination of competing vegetation or changes in physical, chemical, and microbiological properties of soils. The present study was undertaken to provide information on the influence of charcoal alone on germination of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco).

Previous investigations of germination of coniferous seedlings on charcoal yielded conflicting results that may reflect variations in properties of charcoal from different species and differences in methods of investigation (Table 1). Adverse effects were attributed to the action of salts leached from charcoal, which appeared to become more pronounced when the charcoal was in smaller particles. Where beneficial effects were observed, they were ascribed to a germination-promoting agent contained in charcoal or to maintenance of favorable conditions of moisture and temperature on charcoal.

Methods and Results

One-year-old Douglas-fir seeds collected in western Oregon and stored dry in polyethylene bags at 35 F were used in the experiments. Light and heavy seeds were sorted out before the experiments with a device described by Silen (1964) to minimize weight of seeds as a confounding factor. Seeds studied ranged in weight from 13 to 18 milligrams.

Charcoal from charred logs of Douglas-fir was ground to pass a 2-mm sieve. The mineral soil for the experiments was a Brown Latosol taken from the top foot of soil and sieved to remove particles larger than 2 mm.

Experiments 1 and 2 were conducted in controlled-environment chambers at the Oregon State University Forest Research Laboratory. Germination tests

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TABLE 1.

SUMMARY OF EFFECTS OF CHARCOAL ON GERMINATION OF CONIFEROUS SEEDS
+, INCREASE; 0, NO EFFECT; −, REDUCTION

Species	*Germination*	*Type of study*	*Literature reference*
Pinus strobus	+	Nursery	Retan, 1914, 1915
Picea abies	—	Laboratory	Heikinheimo, 1915
Pinus sylvestris	—	"	"
Pinus contorta	+	Field	Bates, 1924
Pinus sylvestris	+	Laboratory	Schmidt, 1929
Abies pectinata	—	Laboratory	Fabricius, 1929
Larix europaea	—	"	"
Picea abies	—	"	"
Pinus nigra	—	"	"
Pinus sylvestris	—	"	"
Picea abies	0	Laboratory	Eneroth, 1931
Pinus sylvestris	0	"	"
Abies grandis	+	Laboratory	Fisher, 1935
Larix occidentalis	0	"	"
Picea engelmannii	—	"	"
Pinus contorta	0	"	"
Pinus monticola	+	"	"
Pinus ponderosa	+	"	"
Pseudotsuga menziesii	+	"	"
Tsuga heterophylla	0	"	"
Thuja plicata	0	"	"
Pinus strobus	—	Laboratory	Tryon, 1948
Larix europaea	0	Nursery	Leibundgut, 1960
Picea abies	0	"	"
Pinus sylvestris	0	"	"
Pseudotsuga menziesii	+	Field	Hermann and Chilcote, 1965

were made in 4½-inch petri dishes with 50 seeds to a dish. The third experiment was conducted on the grounds outside the laboratory.

Experiment 1

The first experiment was designed to determine whether Douglas-fir charcoal contains ingredients that promote or inhibit germination of seeds of Douglas-fir. A factorial design was used involving 10 replicates x 2 temperature treatments (alternating day and night temperatures of (a) 86 and 68 F, (b) 68 and 38 F) x 2 germination media (charcoal and mineral soil) x 2 seed pretreatments (naked stratification for 3 weeks at 35 F and no stratification). Assignment of dishes to temperature treatments was completely randomized.

A 16-hour photoperiod was maintained with both thermoperiods. Source of illumination was "daylight" fluorescent lamps providing 1200 foot candles of light at the dishes.

Substrates were kept moist by applying 4 ml of distilled water every second day under the warm photoperiod and every fourth day under the cool photoperiod. Germination was checked at two-day intervals from the beginning of the experiment for a period of 60 days. Seeds were considered to have germinated when radicles protruded 5 mm and were then removed from dishes.

The 86-68 F thermoperiod resulted in better germination than the 68-38 F thermoperiod, and stratified seeds germinated more rapidly under both conditions of temperature than did nonstratified seeds (Figure 1). With the warm thermoperiod, germination was higher on mineral soil than on charcoal, but with the cool thermoperiod the reverse occurred. Differences among substrates, however, were not significant statistically except for nonstratified seeds exposed to the cool thermoperiod (Figure 1), where germination on charcoal was poor. The low germination probably reflected decreased viability of seeds through heavy fungal infection toward the end of the experiment rather than any inhibitory effect of charcoal itself.

Experiment 2

Results of experiment 1 were not considered sufficient to discount presence of a promotive or inhibitory agent in Douglas-fir charcoal so experiment 2 was carried out to investigate that possibility further. Nonstratified seeds were germinated under two thermoperiods (alternating day and night temperatures of (a) 86 and 68 F, (b) 68 and 38 F) on 5 substrates: (a) charcoal, (b) leached charcoal, and Whatman No. 42 filter paper kept moist with (c) concentrated charcoal leachate, (d) diluted charcoal leachate, or (e) distilled water. Leaching was done by adding 250 ml of distilled water to an equal volume of charcoal in a 1000-ml beaker. Fluid was decanted after three days and passed through a Buchner funnel lined with Whatman No. 5 filter paper. Half of this concentrated leachate was diluted by adding an equal amount of distilled water. Each treatment was replicated 10 times with randomization within treatments. Photoperiod, light intensity, moistening schedules, germination counts, and duration of test were the same as in the previous experiment.

Amount and speed of germination varied significantly at the 5 per cent level within, but not between, treatments. No effect of charcoal or charcoal leachates on germination was apparent under either combination of temperatures. Temperature was the only environmental factor influencing germination (Table 2). Differences between thermoperiods were significant at the 1 per cent level of probability.

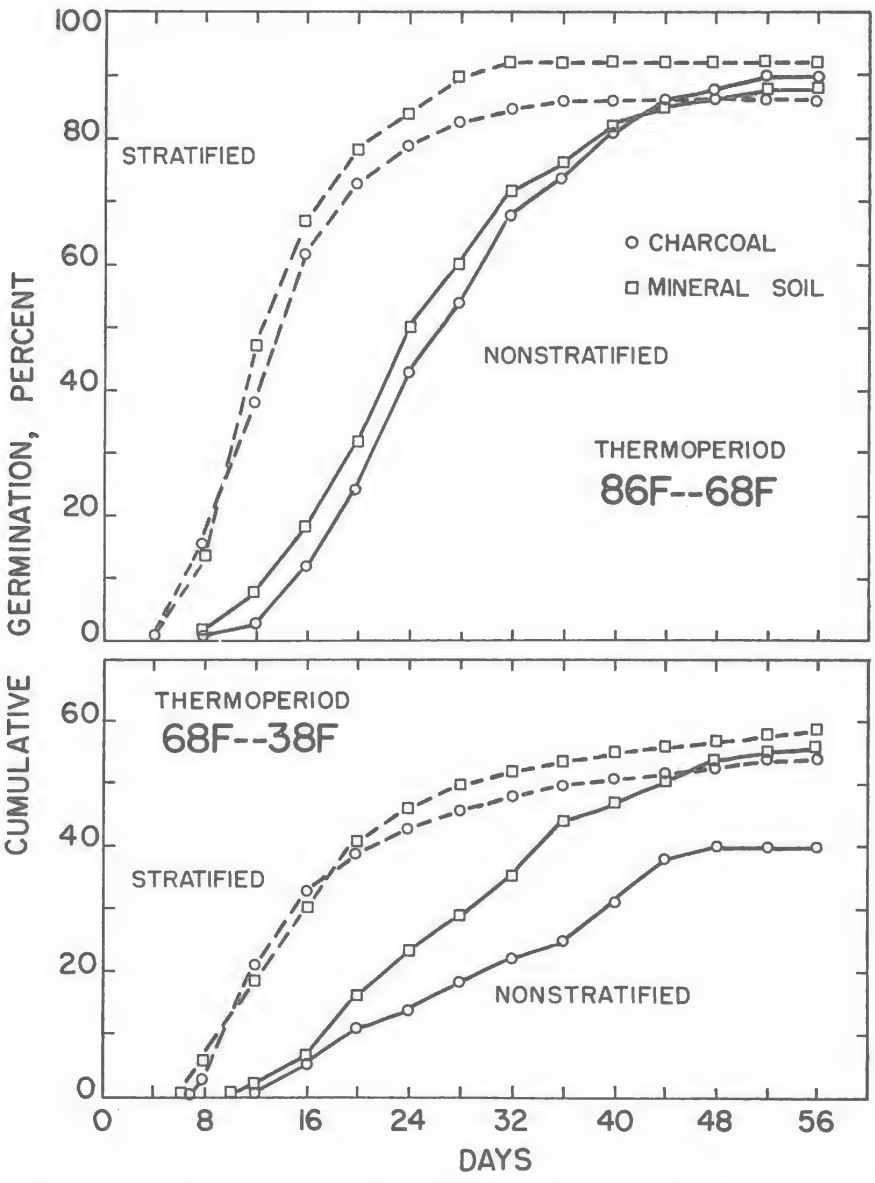

Figure 1. Germination of Douglas-fir seed on charcoal and on mineral soil in a growth chamber (daytime temperature 86° F or 68° F, and night time temperature 68° F or 38° F).

TABLE 2.

TOTAL PERCENTAGE OF SEEDS GERMINATED IN EXPERIMENT 2
(Each value is the mean of 10 replicates)

Medium	*Thermoperiod* 86-68 F	68-38 F
Charcoal	77	53
Leached charcoal	81	54
Concentrated charcoal leachate	75	59
Diluted charcoal leachate	80	52
Distilled water	75	60
Mean, all media	78	55

Experiment 3

Experiment 3 was undertaken to determine whether physical characteristics of charcoal affect germination of Douglas-fir seeds. Eight flats, 16 by 16 by 4 inches, were placed on the ground in the open. Four flats contained 4 inches of mineral soil, and the other four were filled with 2 inches of mineral soil covered by 2 inches of charcoal. One hundred seeds were planted on the surface of each flat on September 1, 1963, following three weeks of stratification. Germinants were counted every day for two months.

Before the beginning of the experiment, flats were saturated with water, allowed to drain to field capacity, then weighed. For the next five weeks, flats were reweighed at seven-day intervals and the amount of water that had been lost was added. Temperatures on the surface of the flats were measured on September 15 and 16 with thermocouples connected to a recording potentiometer.

Initial germination was rapid on charcoal (Figure 2). Twenty days after the experiment was begun, over twice as many seeds had germinated on charcoal as on mineral soil. A *t*-test showed the difference was significant at the 1 per cent level. After 30 days, however, germination on mineral soil nearly equaled that on charcoal, and differences were not significant.

Daytime temperatures on charcoal exceeded those on mineral soil by as much as 8 degrees on September 16 (Figure 3). Similar differences probably existed during most of the first four weeks of the experiment because cloud cover was rare during that period. Loss of water from flats with mineral soil was, on the average, 0.2-0.3 pound greater than from flats with charcoal.

Discussion

The stimulating effect of high temperature and stratification on germina-

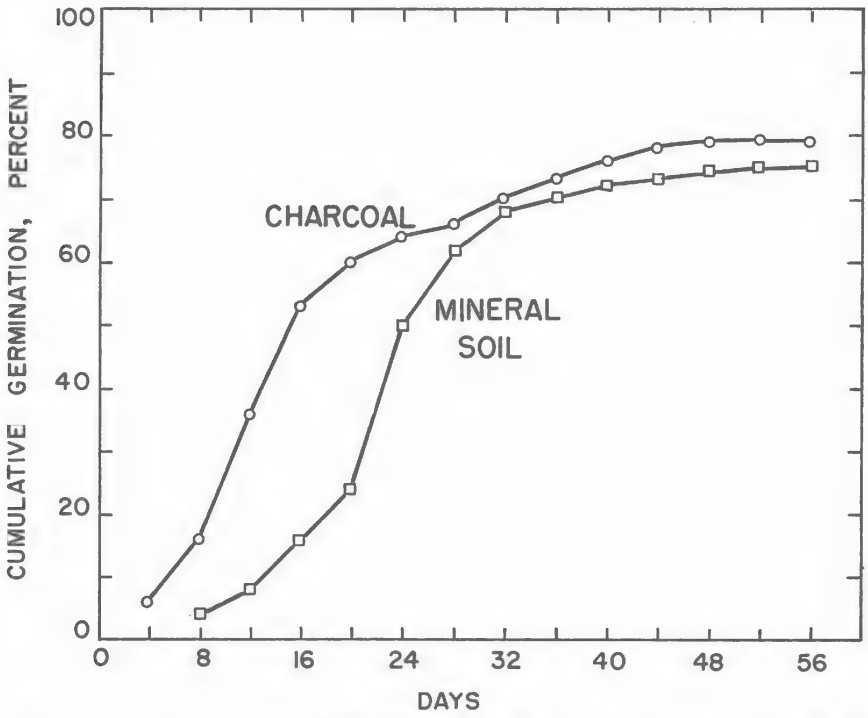

Figure 2. Germination of Douglas-fir seed on charcoal and on mineral soil in the open.

tion of Douglas-fir seed, reflected by data presented here, is well known. Germinative response of Douglas-fir seed to temperature, however, may vary considerably, depending on length of stratification, origin, moisture content, and age of seeds (Allen, 1960, 1962a, 1962b). Exposure of Douglas-fir seeds to long photoperiods appears to change response to temperature in a manner similar to that of stratification (Richardson, 1959). Charcoal-induced changes of dependence of germination on temperature (Borris, 1941) or light (Mes, 1953) have been demonstrated in seeds of angiospermous plants and were attributed to inactivation or absorption of inhibitors. Findings of the present study do not indicate any such effect of Douglas-fir charcoal on Douglas-fir seeds.

The high rate of initial germination on charcoal in the flats kept outdoors was another indication of the stimulating influence of high temperature and supports the view that beneficial effects of charcoal on germination on burned-over areas are a consequence of providing favorable conditions of temperature (Bates, 1924; Hermann and Chilcote, 1965). Charcoal is warmed rapidly by

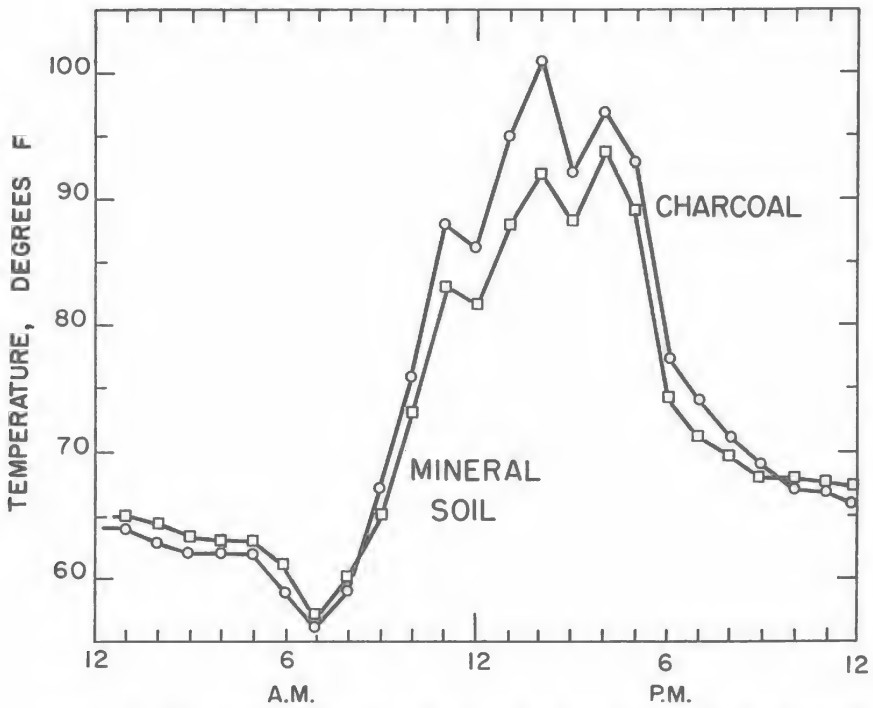

Figure 3. Temperatures on surface of charcoal and mineral soil on September 16, 1963.

insolation and can reach temperatures conducive to germination early in spring. By the time other seedbeds attain such temperatures, not enough moisture may be left for optimal conditions of germination, resulting in emergence of fewer seedlings. If precipitation continues late into spring, or seedbeds are kept moist, as in our experiment, effect of charcoal probably will not be reflected by total germination.

Another benefit of charcoal not investigated in the present study may be certain fungicidal properties. Addition of charcoal to soil has been successful as a preventive measure against damping-off fungi in nurseries in America (Commonwealth of Pennsylvania, 1930) and Europe (Boyce, 1925; Beltram, 1963; Radovanovic, 1962).

Beneficial as charcoal may be for germination, it may be at the same time a severe hazard to newly germinated seedlings. Particularly in the Pacific Northwest, with its warm, dry summers, seedbeds containing charcoal often reach temperatures lethal to seedlings. Under these circumstances, heavy losses of young trees may cancel gains derived from high germination on charcoal.

Summary and Conclusions

1. Experiments with stratified and nonstratified seeds of Douglas-fir under controlled environmental conditions did not indicate presence of germination promoters or inhibitors in Douglas-fir charcoal.

2. A trial outdoors suggested beneficial effects on germination of Douglas-fir as a result of rapid warming of charcoal early in spring when moisture is still at an optimum.

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Mylodon harlani from La Grande, Oregon

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Eastern Oregon College, La Grande, Oregon

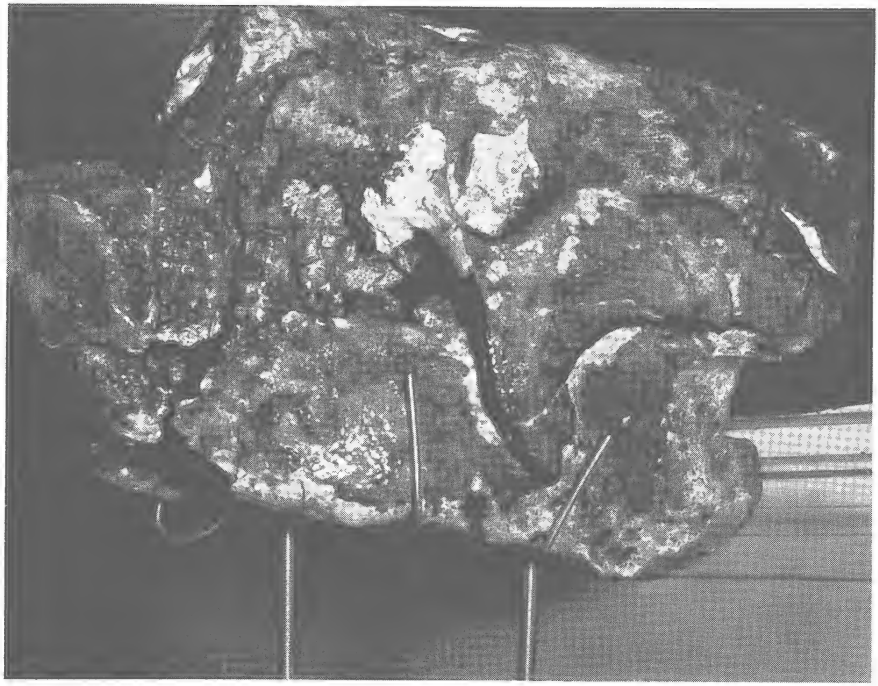
IN OCTOBER, 1964, a fossil Mylodon skull, somewhat battered, but fairly complete, was found in a gravel pit two miles south-southeast of La Grande, Oregon, at lat. 45° 17′ 47″ N, long. 118° 04′ W. It was found in a sandy deposit about seven feet below the contour of the undisturbed material as projected out over the open quarry. Parts of a scapula, a loose caniniform tooth, and parts of radius and ulna and foot fragments including claws were found here. As the skull was cleaned, a tough cemented portion next to the facial bones revealed small, dermal ossicles of calcium carbonate, indicating that the skin had apparently deteriorated in place. Between the inner and outer tables of the cranial bones is a labyrinth of small chambers. It was difficult to get precise measurements to compare with Rancho La Brea specimens tabulated in Stock (1925). However, the approximate measurements fall within those for *Mylodon harlani.* For example, the length from the anterior margin of the maxillary to the posterior end of the occipital condyle (missing) is about 455.0 mm; the depth of the ramus between the third and the fourth inferior teeth is approximately 92.5 mm; the greatest depth of the lower jaw is 181.0 mm. Our specimen shows the shovel-shaped symphysis of the lower jaw.

After correspondence with major museums in the Northwest, as well as at the University of California, I have not yet found any records of an almost complete Mylodon skull from the Pacific Northwest. The few fragments discovered in the Pacific Northwest consist of a tooth here, a jaw ramus there, an ungual phalanx or phalanges, caudal vertebrae, or a humerus.

The earliest record of ground sloths in Western North America was a tooth and a humerus found in 1842 at a depth of 12 feet in an old river terrace of the Willamette Valley, near Eugene. According to Stock (1925: 199), J. Leidy referred these to *Mylodon harlani.*

Cope in 1878, on the basis of fragmentary specimens at Fossil Lake (seven miles northeast of Christmas Lake), established a species, *Mylodon sodalis,* which Lull has considered as synonymous with *M. harlani,* according to Stock (1925: 195).

Stock (1925: pl. 46) presents a photograph of a replica of footprints assigned to *Mylodon harlani,* found in a Pleistocene deposit at the Nevada State Penitentiary, Carson City, Nevada.



Mylodon harlani skull from La Grande, Oregon. Note shovel-shaped symphysis at anterior end of lower jaw (at left of picture). Reminiscent of India in shape, the deep ventral process of the zygomatic arch extends over the ramus.

In 1901, Miss Anne Alexander collected ground-sloth material at Fossil Lake, Oregon. These parts were a first phalanx, the second digit of the manus, a third metatarsal, and two caudal vertebrate (Stock, 1925: 196).

A right ramus of Mylodon, shown in Stock (1925: 196), came from Button Ranch near Christmas Lake, Oregon. Incidentally, this was a large jaw—the depth of the ramus measured between the third and fourth inferior teeth is 105.7 mm.

Hay (1927: 8) reported seeing a Mylodon tooth from Roseburg, Oregon, in a collection in the Portland City Hall. In addition Hay mentions that the distal end of a humerus and the distal end of a femur of Mylodon from near Roseburg, Oregon, are (cat. No. 3000) in the United States National Museum.

The only verified Mylodon material recorded by Hay in the state of Washington are astragali and other foot bones from Delight, about 12 miles north of Washtucna Lake, Adams County.

The La Grande skull and associated bones are at present at Eastern Oregon College. In 1965, material was sent to the Smithsonian for carbon dating. When the age is determined, it will be reported.

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Contents

Volume 40, 1966

No. 1, February

Petrography, chemistry, and possible correlations of the Camas land sill and Teanaway dike swarm, central Washington. David L. Southwick 1
Archives document preservation. Rudolf A. V. Raff, Ivan W. Herrick, and Mark F. Adams 17
Cesium-137 in litter and understory vegetation. W. H. Rickard 25
Seed germination and flowering in Vallisneria spiralis. G. N. Choudhuri 31
Abstracts of papers to be presented at the 1966 meeting of the Northwest Scientific Association 36

No. 2, May

A note on the clay mineralogy of four samples from the Ringold formation. C. D. Moodie, R. Okazaki, H. W. Smith, and J. A. Kittrick 43
Soil development over a hearth in Willamette valley, Oregon. Frank F. Reckendorf and Roger B. Parsons 46
Using soil series to predict site index and wood specific gravity in western Montana. T. C. Carlson and T. J. Nimlos 56
Tidal currents in Yaquina bay. Victor T. Neal 68
Muscular degeneration produced by experimental transport stress in pigs. Norman L. Adel 75
A painted turtle (Chrysemys picta) with ulcers in the stomach and duodenum. Gilbert B. Pauley and Douglas L. Robberson 79

No. 3, August

The genus Phausis in America north of Mexico (Coleoptera-Lampyridae). Kenneth M. Fender 83
Significance of the scarcity of early Pleistocene glacial deposits in the western United States. Eugene H. Walker 96
Artificial ripening of grand fir cones. Robert D. Pfister 103
Vegetation following slash fires on one western Oregon locality. Harold K. Steen 113

No. 4, November

Geology of the Columbia river gorge. Ewart M. Baldwin 121
Weather and climate of the Columbia gorge. Robert E. Lynott 129
The flora of the Columbia river gorge. LeRoy E. Detling 133
Amphibians and reptiles. Robert M. Storm 138
Mammals and the influence of the Columbia river gorge on their distribution. Kenneth Gordon 142
The annual production of the whitefishes Coregonus clupeaformis and C. nasus in Teslin lake, British Columbia. R. V. Boughton and W. A. Clemens 147
Effect of charcoal on germination of Douglas-fir seed. Steven de Keijzer and Richard K. Hermann 155
Mylodon harlani from La Grande, Oregon. Charles W. Quaintance 164

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